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THE PHOSPHATE ROCKS OF ARKANSAS.

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AND

JOHN F. NEWSOM, PH. D.

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R. L. BENNETT, Director,
Fayetteville, Ark.

INTRODUCTION.

This bulletin differs from our previous bulletin in that it relates to phosphate deposits of North Arkansas and not to agricultural experiments.

The material for this bulletin is taken from notes and observations made by Dr. J. C. Branner while State Geologist of Arkansas; also from notes made by him while on subsequent trips to the region, and from notes made by Dr. J. F. Newsom while doing private work in the phosphate region. Both of these gentlemen are now in the Faculty of Leland Stanford Junior University.

The bulletin is issued to furnish information and to encourage the development of these phosphate deposits, which promise to be of great extent and richness.

The most important Arkansas deposits now known are in north-central Arkansas, lying within parts of the counties of Independence, Stone, Izard, Searcy, Marion, Baxter and Newton. The deposits of this locality are now attracting attention, as two railway companies are building lines into the region. One line is building up White River from Batesville, on the north side of the phosphate area, and the other line is building southeast of Harrison through the south side of the locality. These two railways in providing transportation, will render possible the development of the phosphate deposits, which have heretofore been without transportation.

One company, the Arkansas Phosphate Company, on the line north of Batesville, is now manufacturing acid phosphate. The rock this company is mining works up into a dry, friable acid phosphate. This rock is soft and easily crushed, and in appearance is identical with some of the Tennessee phosphate rocks.

The deposits of this region promise to be of considerable extent and richness, and with the extension of these lines of transportation development of the deposits will doubtless begin at various points at an early date.

R. L. BENNETT,
Director of Experiment Station.

Acid Phosphate Plant of the Arkansas Phosphate Co., Phosphate, Arkansas.

THE PHOSPHATE ROCKS OF ARKANSAS.

By John C. Branner, Ph. D., and John F. Newsom, Ph. D.*

The phosphate rocks of Arkansas occur in three different regions: the *first,* and probably the most important, lies north of the Boston Mountains and west of Black River; the *second* is in the Cretaceous area of the southwestern part of the state; it is possible that there is a *third* north and west of the City of Hot Springs.

The phosphate rock itself is an earthly mineral and not of a kind that attracts attention, and it is doubtless for this reason that this mineral has not sooner become known in the State of Arkansas. Indeed the senior author had traced these rocks for hundreds of miles across north Arkansas without suspecting their true nature. About 1895, we had an analysis made of some of the dark lumps found in what is called the Sylamore sandstone of North Arkansas. These lumps turned out to be phosphate nodules, and led to a more careful examination of the nature and occurrence of these materials.

The discovery of phosphate deposits in the State of Arkansas is a matter of importance to the people generally, but it is of especial interest and importance to those who live in the regions in which the deposits are found. And this importance comes, not from the increased value of the lands alone, but from the new source of income to the people, and the increased activity likely to follow the development of the phosphate mines.

Some idea may be had of the importance of the phosphate mining industry of the United States from the amount and value of the production. In 1891 the total amount was 587,988 long tons worth $3,651,151, in 1895 this amount had risen to 1,038,551 tons worth $3,606,094; and in 1899 to 1,515,702 tons worth $5,084,076.† And this

*We are under obligations to Col. J. C. Yancey of Batesville, Ark., for permission to use the data collected for him by the junior author, and also for the use of the analyses given in this paper credited to Davis & Lyons and to J. Ross Hanahan as analysts.

†These figures are taken from E. W. Parker's article upon phosphate rock in the 21st Ann. Rep. U. S. Geological Survey, Vol. VI. (continued), p. 481.

increase has taken place in spite of the fact that the price of phosphate rock, owing to competition at home and to the importation of foreign fertilizers, has fallen from more than six dollars a ton in 1891 to less than three dollars a ton in 1899.

Although phosphate rocks are known and mined extensively in Tennessee, in South Carolina and in Florida, the Arkansas beds are the only ones thus far discovered so near the center of the great agricultural region of the Mississippi valley. This fact alone ought to be worth much to the people of the state.

The present report contains all that is now known of the character and distribution of phosphate rocks in the state. Our knowledge is necessarily incomplete, but enough is here presented to show the importance of having these deposits thoroughly studied, and the locations and characters of the more important ones pointed out.

The mining of phosphate rock is on the whole quite simple. No expensive machinery or appliances are required. The mining will be done at first in open cuts on the sides of the valleys. In the course of time, however, tunnels will have to be run in the hills, and it will be necessary to provide for draining, ventilating and timbering the mines.

The phosphate beds are for the most part horizontal and for this reason the rock forming the floor and roof at the mouth of a tunnel may be expected to form the floor and roof of tunnels where they are driven into the hills.

It will be seen from the following detailed description that phosphate rock occurs over a very large area in north Arkansas. One should distinguish at the outset, however, between the *phosphate deposits* of workable dimensions and the *phosphate horizon*. By phosphate horizon is simply meant the position in the rocks in which the phosphates occur when they occur at all. The deposits of workable size and importance are local developments within this horizon. The phosphate horizon is several hundred miles in length, while the workable beds are of limited extent. It is the object of the present paper not only to describe the known deposits, but to give the location of the phosphate horizon in order that prospectors and land owners may know where to seek the paying deposits.

THE NORTH ARKANSAS PHOSPHATE ROCKS.

Origin of the Rocks.—The phosphate deposits are not scattered over the country at random, and neither are they confined to fissure

veins like certain metals, but they occur at a definite place in the rock series, and unless one understands the general geology of the region his search must be unsystematic and much time and energy must be wasted. It is therefore necessary to explain as briefly as possible the origin of these rocks and the general structure of the region.

The rocks of the region north of the Boston Mountains are all what are known among geologists as *sedimentary,* that is, they were deposited as sediments in water. This fact any one can determine for himself by a close examination of almost any of the rocks in that region. The sand grains of the sandstones and the pebbles of the conglomerates are rounded and water worn, and the rocks are all water-bedded, that is, they show the statification planes found in sands and clays laid down in water. The water in which these sediments were laid down was salt water; this is shown by the fact that the rocks over this region contain the remains or impressions of the animals that lived and died and sank to the bottom along with the sediments themselves. These remains are all of such animals as are now known to live only in the salt water of seas and oceans: corals, crinoids and many mollusks such as live only in salt waters.

Although this region is now a hilly and even a mountainous one, the sediments were originally laid down in broad horizontal sheets, like the sediments now being deposited. In some cases these sheets, layers or beds spread across the entire area covered by the northern part of Arkansas; in other cases they varied considerably from place to place, here being more sandy and there containing more clay or more lime. In the course of time the area over which these beds were deposited was gradually lifted from beneath the water and became dry land. When so elevated the rain that fell upon the surface gathered in streams and these streams began the work of cutting their channels down through these sediments, and that work has gone on without interruption to the present day. If the continuity of the sediments or rocks is interrupted in many places it is because the streams have cut down through them and washed parts of them away. In some cases, however, the movements of the earth's crust has caused the beds to break and slip so as to form what geologists call faults or displacements. In other cases the squeezing or side pressure upon the rocks has thrown them into gentle folds. Whenever the rocks are tipped up on edge or lie at an angle other than nearly horizontal it is because they have been wrinkled up in this way.

With these general principles in mind any one who will watch the

positions, conditions, and characters of the rocks in the region under consideration, can soon learn to locate and trace the phosphate beds.

Attention should be directed to the fact that wherever the phosphate rocks occur upon the brow of a mountain, or on the steep slope of a hill, as the accompanying beds decay or are undermined, or for any other reason become loosened and broken, they all have a tendency to roll down these slopes and to mingle with the soil and broken rock fragments in the valleys. For this reason one frequently finds fragments both large and small at considerable distances from the beds from which they were derived. In regard to loose pieces generally, it is well for the prospector to bear in mind that all fragments have a tendency to work down hill, and no tendency at all to work up hill. They can therefore be used to find the bed in place by going up the slope from the points at which they are found, and keeping an outlook for other fragments of the same material. Where these fragments come to an abrupt end one may safely assume that the undisturbed bed is close at hand.

In this connection it should be noted that the outcrop of any bed one may attempt to follow is more or less concealed by soil or by the fragments of decaying rocks, to say nothing of the concealment caused by dead leaves, or by grass, underbrush, or forests. So long as the bed of rocks lies undisturbed in its horizontal position this concealing of the outcrop does not seriously interfere with the tracing out of its course and position, for from one exposure to another one only needs to keep at or near the same elevation in order to trace it. When, however, the beds are faulted or folded the covering up of the outcrops make the tracing out of any particular bed a matter of much more difficulty and it becomes necessary to study the structure of the folded or faulted region in order to know just where to look for any particular horizon.

Geologic Position of the Phosphate Deposits.—During the progress of the geological survey of Arkansas in the northern part of that state, it was found that the interval between what are known to be Ordovician rocks below and recognizable Lower Carboniferous rocks above contains no representatives, or but poor representatives, of the whole Silurian and Devonian series. In some places one passes in the space of a foot from Ordovician rocks to lower Carboniferous ones; at other places this interval is three or four feet thick, but it is generally concealed by the decay of the black shale—the Eureka shale—which fills it, so that for a long time it was passed over undetected. It was only after considerable work in the region and by the

valuable palæontologic work of Dr. Henry S. Williams, of Yale University, who kindly accompanied the senior author on a trip through this part of the State, that the importance of this interval came to be recognized, and the thin beds occupying it to be carefully studied. It then appeared that this interval was occupied, for the most part, either by a greenish or black shale or by a sandstone; and eventually the sandstone was found to have a maximum thickness of 40 feet on South Sylamore Creek in 15 North 11 West, Section 21. It was therefore called the Sylamore sandstone, a name frequently used in the following pages.

The shale of this interval is generally from three to ten feet thick; it is a constant feature of the geology through Carroll County, and is well exposed in the streets and cuts in and about the city of Eureka Springs, and for this reason it was named the Eureka shale. Its maximum thickness is 50 feet in the northwestern part of Benton County.

The relations to each other of the Sylamore sandstone and the Eureka shale have never been determined satisfactorily; for generally when one is present the other is absent, while on South Sylamore Creek, where both seem to occur, the outcrops are so concealed by the decay of overlying beds that their relations have not been made out.

Analyses of the phosphatic nodules from the Sylamore sandstone are given below. The stratigraphic relations of the phosphates to the Eureka shale were so intimate that analyses were made of both the black and green varieties of the shale. There is, however, no phosphate bed at the point where these samples were collected.

The Marble Report of the Arkansas Survey, Plate X., opposite page 212, gives a group of sections across the northern part of the

Analyses of Eureka shale from Dairy Spring, Eureka Springs, Ark.

R. N. Brackett, Analyst.

	Black Variety. Per Cent.	Green Variety. Per Cent.
Silica, SiO_2	59.33	64.28
Alumina, Al_2O_3	15.51	11.87
Iron oxide, Fe_2O_3	7.57	9.60
Pyrites, FeS_2	3.48	4.32
Lime, CaO	1.05	0.99
Magnesia, MgO	0.79	0.55
Potash, K_2O	5.22	3.12
Soda, Na O	trace	trace
Loss on ignition	7.19	4.42
Totals	100.13	99.15
Water at 110° to 115° Cent.	1.31	2.76

State, showing the varying thicknesses of the Sylamore sandstone and of the Eureka Shale.

The following is a good general description of the Sylamore sandstone, a rock with which the phosphate prospector should be thoroughly familiar.

"The Sylamore sandstone is generally an insignificant bed, being often but a few inches in thickness and readily disintegrated so that it is frequently overlooked even when present. It differs greatly in character in different parts of the area; in some places it is made up of rounded grains of hard crystalline quartz, interspersed with black, rounded, irregular pebbles; in other places it is a soft earthy rock of a yellowish brown color; in still other places an arenaceous shale. The dark colored pebbles are a peculiar feature of this rock, yet they are not always present."*

No description, however, will be as useful to the prospector as familiarity with the rock itself, and for the purpose of obtaining this familiarity, we would suggest a visit to some of the localities at which the Sylamore sandstone is exposed. The same may be said of the Eureka shale which, it will be seen, often takes the place of the Sylamore sandstone.

These two rocks—the Sylamore sandstone and the Eureka shale—are mentioned here simply to point the way to the phosphate-beds of the northern part of the State; for it is in, or associated with, these rocks that the phosphate deposits occur.

This will be plainer after the known deposits are described. It will be seen also that these phosphates occupy the same stratigraphic position as do the Tennessee beds. We have examined specimens of the phosphate rocks of Tennessee, and Mr. Hayes's description of those deposits shows that there are desposits in that State at horizons other than the Devonian interval.†

In north Arkansas we have never seen palæozoic phosphate-deposits known to be elsewhere than in or close to this interval. The precise geologic position of the bed north of Hot Springs is not known further than that they are Ordovician.

We learn from Dr. Safford of Nashvillle, of a discovery of an important bed of phosphate rock in what he calls the Capitol limestone. This limestone is the equivalent of the St. Clair marble of north

*Ann. Rep. Geol. Sur. Ark. for 1890, Vol. IV., Marbles and Other Limestones, by T. C. Hopkins. Little Rock, 1893, pp. 212-213.

†"The Tennessee Phosphates." By C. W. Hayes, 16th Ann. Rep. U. S. Geol. Sur., pp. 610-630.

Arkansas. It is exposed at and about St. Clair Springs, along Polk Bayou, Cave Creek, Coon Creek, Spring Creek, East Lafferty Creek, Blowing Cave Creek, West Lafferty Creek at Penter's Bluff, on Wilson Creek, and at many other places in Independence County.

Several analyses have been made of the Saint Clair marble, but we have never found the solid marble to contain more than one per cent. of phosphoric acid. It should be remembered, however, in a farther examination of this horizon that the samples analyzed were collected with a view to finding a marble, whereas this same bed may at other points be loose and earthy and may contain enough phosphoric acid to make it important. This suggestion is based upon the experience of this rock by the Tennessee phosphate owners. The distribution of the St. Clair bed is shown in the marble report of the Geological Survey of Arkansas, on the maps covering the área from Batesville west to about twelve miles west of Mountain View in Stone County, and also on the maps accompanying the survey's report upon zinc and lead.

The geological position of this and of the other beds will be understood from the following section in which the highest beds mentioned are placed at the top and the next lower ones just below.*

		Maximum Thickness, Feet.
Lower Carboniferous or Mississippian	Boston group (shales, limestones, sandstones, cherts)	780
	Batesville sandstone	200
	Fayetteville shale	300
	Boone chert and limestone	370
Devonian	Slymore sandstone } phosphate horizon	40
	Eureka shale } phosphate horizon	50
Silurian	St. Clair marble	155
Ordovician	Izard limestone	285
	Saccharoidal sandstone, Magnesian limestone, Sandstone, cherts, etc.	1750+

By means of this section any one at all acquainted with the geology of the region can readily find the interval at which the phosphate beds are to be looked for. It will be seen that this phosphate horizon is probably of Devonian age, that the beds occupying it are relatively thin, and that these beds are for the most part, either sandstones or shales. And it may be added that it is the local variation or development of these beds that produces the phosphate deposits themselves.

*For a discussion of the ages of the rocks of the phosphate region of North Arkansas, see Chapter VII. of the Zinc and Lead Region of North Arkansas, by J. C. Branner, Little Rock, 1900.

As any one who is acquainted with north Arkansas knows the region here under discussion is a hilly one. The rocks forming the beds mentioned above lie in horizontal sheets, and through these streams have cut steep sides gorges from 50 to 500 feet deep, along whose sides the various rocks outcrop. These hills, valleys and slopes are heavily timbered, except in certain parts known as the "flint hills," where the soil is thin and rocky, and the timber rather stunted in growth.

Appearance of the Phosphate Rock.—The phosphate rock is for the most part in the form of irregular lumps, commonly called pebbles or nodules. These lumps vary greatly in size, color and form. Sometimes they are no larger than a pinhead, and from this they vary up to the size of a hen's egg, and are even larger. They are sometimes gray, often of a light yellowish-brown or buff color (and where the rock is made up almost entirely of the nodules they are generally of this buff color), and they are also often quite black. The large black ones have often been found to contain fossils, especially *Lingula*. The black nodules are hard and rock-like, and break like a compact limestone. The light-colored ones are more earthy, possibly on account of weathering. In form they are very irregular, are frequently pitted or indented over the outer surface, and look like so many small Irish potatoes; often they are flattened or oblong. Specimens of the different varieties will be placed on exhibition at the Agricultural Experiment Station at Fayetteville.

Origin of the Deposits.—A knowledge of the method by which these deposits were formed would probably aid us to understand their distribution and help us in search for the richest localities. These three facts should be kept in mind by every prospector:

1. That they occupy the geological horizon of the Devonian rocks as shown in the table above.

2. That they are, in the main, conformable with the rocks both above and below them.

3. That they vary much in thickness and character.

The fact that Silurian and Devonian time is represented in north Arkansas by a very thin deposit compels us to believe, either that the region was not under water in Devonian time, or else that, being under water, it was so far from the shore and the water was so deep, or for some other reason, that almost no sediments were laid down over this part of the sea bottom during this long period. We are not disposed to believe that these deposits were made as surface-accumulations like many of those of South Carolina; the regular and undisturbed condition of the upper surface of the underlying beds across a region of

a hundred miles wide in northern Arkansas, is as nearly perfect as we are accustomed to find it in any sedimentary deposit. A land surface so smooth and regular appears to be out of the question. We are, therefore, reduced to the necessity of believing that this interval, with its phosphate-deposits, represents the slow accumulation of organic matter over a comparatively deep sea (not abyssal, however) during the Silurian and Devonian periods. In other words, these phosphate beds are probably the droppings of fishes and other marine animals and accumulations of organic matter that settled to the bottom of the quiet waters that covered this part of the world during Silurian and Devonian times.

DESCRIPTION OF KNOWN LOCALITIES.

North and East of Batesville.

Fourteenth North, Five West, and Eastward.—The most easterly exposures of the phosphate beds now known are in the vicinity of Hickory Valley in Independence county. A systematic search for the line of contact between the St. Clair marble and the Boone chert beds, may lead to the discovery of these beds somewhat farther east. They will not be found east of Black River, however, for the Palæozoic beds are cut off just west of that stream, and are overlapped by the Tertiary and later beds that cover all eastern Arkansas.

The deposits near Hickory Valley are at Mr. Milligan's place, twelve miles northeast of Batesville, in 14 North, 5 West, section 6. The rock here looks like a conglomerate or pudding stone, and is exposed at the mouth of a cave in a hill side, where it forms beds with an aggregate thickness of about 12 feet. The beds rest upon the St. Clair marble, but the top is concealed by the chert debris.

The following section is exposed at the cave at the Milligan place. (Fig. 1).

Bed No. 1, Five feet of brown, pebbly phosphate rock, with some chert fragments.
" " 2, Two feet of cherty fragments with some phosphate pebbles.
" " 3, Eighteen inches of rich pebbly phosphate rock, brown in color, bleaching gray.
" " 4, Marble, twenty inches.
" " 5, Thirty-three inches of pebbly phosphate rock, with some chert mixed in.
" " 6, Ten inches of cherty material.
" " 7, Twenty-two inches of phosphate conglomerate with a slight mixture of chert.
" " 8, Fifteen inches of cherty material.
" " 9, Eighteen inches of apparently rich phosphate conglomerate, exposed in the bottom of the pit.

Analysis by J. Ross Hanahan, analyst, of Bed No. 1 of this section showed it to contain 47.19 per cent. calcium phosphate. ($Ca_3P_2O_8$.)

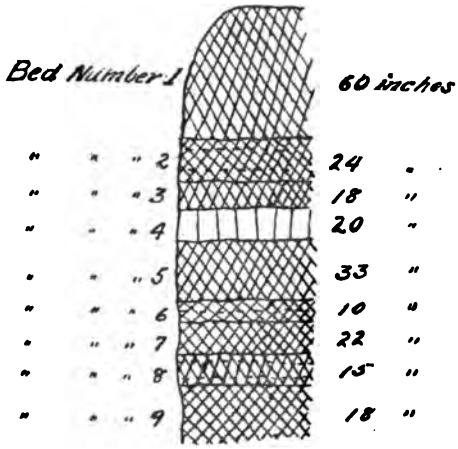

Fig. 1. Section of the phosphate rock exposed in the old cave at Milligan's. The St. Clair marble is a short distance below bed No. 9.

At a pit on the point of the hill a short distance west of the old cave at the Milligan place the following section is exposed (Fig. 2).

Bed No. 1, Covering of soil and debris, one to two feet.
" " 2, Six inches of brownish phosphate conglomerate.
" " 3, Three feet of light gray phosphate conglomerate apparently a rich rock to the bottom of the pit.

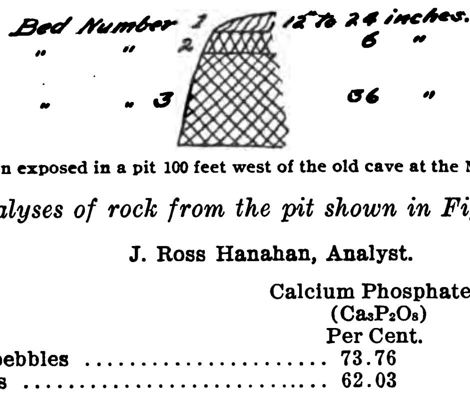

Fig. 2. Section exposed in a pit 100 feet west of the old cave at the Milligan place.

Analyses of rock from the pit shown in Fig. 2.

J. Ross Hanahan, Analyst.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Alumina & Iron. (Al_2O_3 and Fe_2O_3) Per Cent.
Washed pebbles	73.76	3.82
Fragments	62.03	2.97

Much of the rock at the Milligan place occurs with but little overburden and could be mined by stripping.

The two pits of which sections are shown in Figs. 1 and 2, are within about one hundred feet of each other. The hillsides in the

neighborhood are thickly covered with chert fragments, making it very difficult to give an estimate as to the acreage and quantity of rock to be found on this tract of land. If the deposit is continuous back into the hills, as is the case with most of the other deposits of which we know, there are probably 10 acres of phosphate rock here. The aggregate thickness of the phosphate exposed in the old cave, which reaches about the bottom of the deposit, is approximately twelve feet. This rock weighs about 150 pounds to the cubic foot as it lies in the ground. Taking eight feet as an average thickness, the amount of rock indicated would be about two hundred and thirty-two thousand (232,000) tons, if an area of ten acres is covered.

Systematic prospecting will be necessary before the acreage and quantity of rock at the Milligan place can be known positively.

The following analyses show the deposit at this locality to be of good quality. Samples were collected and analyzed from inside the cave and from boulders and loose fragments outside of the cave. The analyses were made in duplicate in each case in order to avoid the possibility of any serious mistake.

Analyses of phosphate rock from the Milligan Place, near Hickory Valley, Independence County.

	Per Cent.	Per Cent.
Samples from inside of the cave.*		
Phosphoric acid (P_2O_5)	26.13	26.77
Equivalent to calcium phosphate ($Ca_3P_2O_8$)	57.03	58.43
Iron and alumina	5.89	5.86
Second set of samples from inside of cave.*		
Phosphoric acid (P_2O_5)	29.40	29.98
Equivalent to calcium phosphate ($Ca_3P_2O_8$)	64.17	65.43
Iron and alumina	3.08	3.87
Samples from boulders outside of the cave.*		
Phosphoric acid (P_2O_5)	31.06	31.11
Equivalent to calcium phosphate ($Ca_3P_2O_8$)	67.79	67.90
Iron and alumina	8.01	7.05
Samples from fragments outside of cave.*		
Phosphoric acid (P_2O_5)	33.54	33.86
Equivalent to calcium phosphate ($Ca_3P_2O_8$)	73.20	73.90
Iron and alumina	5.19	5.09
Calcium phosphate¶ ($Ca_3P_2O_8$)	62.03	
Iron and alumina¶ (Fe_2O_3 and Al_2O_3)	2.97	
Washed pebbles.		
Calcium phosphate¶ ($Ca_3P_2O_8$)	73.76	
Iron and alumina¶ (Fe_2O_3 and Al_2O_3)	3.82	

*Maxwell Adams, Analyst.
¶J. Ross Hanahan, Analyst.

The richness and thickness of the deposit and the comparatively short distance to the railway are sufficient reasons for carefully examining the phosphate horizon east and west of this locality. To the east the phosphate horizon cuts across the northwest corner of Section 5 and runs into the southwest corner of section 32 of 15 North, 5 West. Here it bends to the east and passing south of the middle section crosses the west line of section 33 a short distance south of the middle and thence extends to near the fork of the road at the middle of this section. From this point the phosphate horizon cuts across the northeast corner of section 4, in 14 North, 6 West, then swings northeast and crosses the north side of section 3 just west of the middle of that side. From this point it follows an irregular course through the southern parts of sections 34 and 35 and at the southeast corner of section 35 it strikes southeast through section 1 and crosses the east side of this last section about a quarter of a mile north of its southeast corner.

This horizon is found along North Dota Creek on both sides from near Convenience post-office eastward to near the northeast corner of section 18 of 14 North, 4 West. The exposure on the west side of North Dota Creek continues along that stream and about a quarter of a mile away from it to Charlotte post-office in the southeast corner of section 29 of 14 North, 4 West, and here it bends suddenly toward the west and follows up South Dota Creek to near the northwest corner of section 31 where it crosses to the south side of this last named stream. On the south side of South Dota Creek it follows the course of the creek to where it enters Dota Creek proper and then it turns south and follows down Dota to the middle of section 4 of 13 North, 4 West where it crosses to the east side of the stream and follows it again towards the north. A reconnoissance of the horizon between Hickory Valley and North and South Dota Creeks, made by the junior author, failed to discover any phosphate deposits in that region; not enough work was done there, however, to certainly prove their absence. In the region lying between Dota and Black River we are unable, at present, to indicate the location of the horizon at which the phosphates are to be sought.

Fifteen north, six West. Northeast, north, and northwest of Hickory Valley, there are several outliers of Boone chert resting upon the Izard limestone of the Ordovician. The more important of these are as follows: in 15 North, 5 West, section 24, the phosphate horizon crosses to the east side of the section just south of the middle, extends west and south with a ragged edge and at the middle of the south side

of the section passes into section 25. From this point the horizon swings eastward and crosses the east side of the section about the middle. The eastern limits of this area we are unable to give at present. Another Boone chert area extends from the southwest quarter of section 25, in a northwestern direction to the middle of the south side of section 23, of the same township and range (15 North, 5 West). The total length of the contact along which phosphate rock is to be sought here is about three miles.

In 15 North, 5 West, section 22, there are three areas in which the Boone chert rests upon Ordovician rocks. One of these extends from the southwest quarter of section 23 in northwestern direction across section 22 and ends a little north of the middle of that section. A second area lies across the south side of the section and projects into the northeast quarter of section 27; it ends on the north at the road running northeast-southwest through this section about a half a mile northeast of Curia post-office. The third area in this section (22) lies on the water-shed at the middle of the west side of the section; its longer axis points toward the northeast.

Due north of Hickory Valley, and three miles away a small area of Boone chert rests upon the Ordovician rocks in the northeast quarter of section 19, 15 North, 5 West. This area is about half a mile southwest of the village of Loyal. In this same section (19), southwest quarter, and lying between Curia Creek and the west side of the section, is another small area in which the phosphate rock may be sought.

Fifteen North, six West.—Northeast of the village of Sandtown, in 15 North, 6 West, section 22 is a long narrow strip of Boone chert resting upon Silurian rock. This rock extends from the center of the section due and nearly to the center of section 23. In the northwest quarter of section 26 (15 North, 6 West), a small area of Boone chert resting upon Ordovician rocks, extends for a short distance into section 27. In this same section (27) there is a small area of the phosphate horizon lying very close to, but on the west side of the center of the section. West and southwest of Sandtown the phosphate rock is to be looked for in all the openings made for manganese. A mile or two mest of Sandtown there is a north-south belt about a mile wide and six miles long over which the Izard limestone is the surface rock. This same rock comes to the surface over a belt some four or five miles wide extending from near the mouth of Sullivan Creek westward to near west Lafferty Creek. It is also exposed along Coon Creek and thence to the northeast to and beyond Curia post-office, and also in patches of

various sizes and shapes about Loyal. The close association of the phosphate rock and the manganese ore, and the occurrence of the manganese over this area, suggest the advisability of a search being made here for the phosphate rock. This search can be safely confined however, to the top of the hills over the Izard limestone region.

Fourteen North, six West.—Southwest of Hickory Valley the phosphate horizon extends from a point just south of the northwest corner of section 6 (14 North, 5 West), along the bottom of the Boone chert bed which crosses section 1 (14 North, 6 West) in the direction of its southwest corner. This line crosses the west side of section 11 a few hundred feet south of its northeast corner and runs almost due west across section 11. On entering section 10, it makes a bend to the south, and swings round the head-waters of a small stream that drains into Coon Creek, and crosses into section 9 about a quarter of a mile south of the northeast corner of 9. Across this section the horizon runs nearly due west till it passes into section 8 when it swings due south. With more or less irregular outline it passes through the eastern portions of sections 8, 17 and 20 to the near confluence of Polk Bayou and Cave Creek. This same horizon occurs on both sides of Cave Creek and well up the hill slopes from where it enters Polk Bayou to where it heads in sections 11 and 12, 14 North, 6 West.

The phosphate horizon also occurs along Polk Bayou from the mouth of Cave Creek down to the ford in the northwest corner of section 4, 13 North, 6 West, and also up the stream that enters Polk Bayou at this ford coming in from the northeast through section 33, of 14 North, 6 West. To the east of the ford just mentioned the phosphate horizon extends into sections 33 and 34 of 14 North, 6 West and into sections 4 and 3 of 13 North, 6 West. In the vicinity of St. Clair Spring this horizon occurs in the western half of section 18, 14 North, 5 West, and all along Miller Creek in section 24, 14 North, 6 West.

West of Polk Bayou (in 14 North, 6 West) the phosphate horizon extends northward through the west half of section 32, and to the center of the southwest quarter of section 29, where it suddenly turns west and enters the east side of section 30, where it turns northward to the northwest quarter of the northeast quarter of section 30. Here it turns back southeastward around the head-waters of the small stream that enters Polk Bayou from the west, and passes into the northwest quarter of section 29, where it turns back northwestward on the west side of Polk Bayou. It passes through the southwest corner of section 20, through section 19, and enters township 14 North, 7 West, about a quarter of a mile north of the southeast corner of section 24.

Throughout much of the region above mentioned manganese has been mined or prospected for, and as the phosphate rocks generally overlies the manganese the latter mineral may frequently serve as a guide to the prospector for phosphate rock. This statement is equally true in the neighborhood of Cushman.

In 14 North, 6 West, the phosphate rock has been observed at the localities described in the succeeding paragraphs.

St. Clair Spring.—On the west slope of the hill 150 yards southeast of St. Clair Spring in the northeast quarter of section 24, 14 North, 6 West are fragments of a greenish phosphate limestone. The thickness here, as indicated by these fragments, is probably from 18 inches to 2 feet. Analysis* of this rock gave—

Calcium phosphate ($Ca_3P_2O_8$), 48.27 per cent; Alumina (Al_2O_3), 1.40 per cent; Iron (Fe_2O_3), 4.21 per cent.

Fragments of greenish, phosphatic limestone are found also about one-half mile south of St. Clair Spring on the west slope of the hill. The fragments in this vicinity do not indicate thick or extensive beds.

O'Flynn Shaft—In the southwest quarter of the northeast quarter of section 22, 14 North, 6 West, at the O'Flynn shaft is a deposit of phosphate rock highly stained with iron. The rock is apparently phosphatic down to and below the mouth of the O'Flynn shaft. This deposit which does not extend back into the hill, is about 200 feet long and 150 feet wide at its widest part, while its greatest thickness appears to be about 15 feet.

A quarter of a mile northeast of the junction of Cave Creek and Polk Bayou, near the top of the ridge and on its eastern slope, in the northeast quarter of section 29, 14 North, 6 West, are numerous fragments of conglomeritic phosphate rock. These fragments can be traced laterally for about 100 feet. The ridge is quite narrow here, and cannot contain a large amount of the rock. The surface fragments indicate a thickness of from three to four feet. No fragments of phosphate rock were observed northward along the eastern slope of the hill; this portion of the hill, however, should be carefully prospected by pits or shafts. This deposit is four miles from Batesville. Analysis (by Davis and Lyons) of this rock gave:

Calcium phosphate ($Ca_3P_2O_8$), 43.61 per cent; Alumina (Al_2O_3), 11.93 per cent; Iron (Fe_2O_3), 11.07 per cent.

Phosphatic pebbles and soft, yellow phosphate rock are thrown out from the old manganese openings near the head of the easternmost ravine that extends southward through the northeast quarter of section 30, 14 North, 6 West. These openings are about a half mile up

*Davis and Lyons, analysts.

the ravine (north) from the "big spring" which is located about one-half mile due west from the mouth of Cave Creek.

Many black phosphate pebbles are found about the mouth of the manganese opening furthest up the ravine on the west side. Analysis of these pebbles (by Davis and Lyons) gave:

Calcium phosphate ($Ca_3P_2O_8$), 72.54 per cent; Alumina (Al_2O_3), 3.80 per cent; Iron (Fe_2O_3), 4.84 per cent.

Light yellow phosphate rock was passed through in the pits further down the valley and on its east side. Analysis (by Davis and Lyons) of this rock gave:

Calcium phosphate ($Ca_3P_2O_8$), 49.62 per cent; Alumina (Al_2O_3), 3.63 per cent; Iron (Fe_2O_3), 16.70 per cent.

No estimate of the thickness here can be given without sinking prospect pits. This locality should be carefully examined by sinking such pits.

In section 23, 14 North, 7 West, near the northeast corner of the northeast quarter of the southeast quarter at an old manganese opening near the head of the ravine, and outcropping on the east side of the ravine, are large fragments of dark grayish phosphate rock, indicating a deposit at least 3 feet thick. The deposits can be traced for 50 yards along the east side of the ravine when they are lost under the debris which is very thick at this point. The deposit is two and a half miles from the railroad. An analysis of this rock (by Davis and Lyons) gave:

Calcium phosphate ($Ca_3P_2O_8$), 36.07 per cent; Iron (Fe_2O_3), 19.50 per cent; Alumina (Al_2O_3), 0.33 per cent.

Other localities in 14 North, 6 West, where phosphatic rock has been observed are the following:

Near the center of the north half of section 33, on the south slope of the hill are small fragments of conglomeritic phosphate. A prospect pit here shows the bed to have a thickness of about one foot.

In section 29, the southwest quarter on the west side of Polk Bayou, slightly south of a point directly opposite the Blowing Cave, and 100 feet above the valley; on the northeast slope of the hill is a greenish phosphate rock; phosphatic limestone with pebbles occurs on the east slope of the hill near the center of the northwest quarter of section 29; on the east slope of the hill in the northwest quarter of the northwest quarter of section 29, the phosphate bed is about two feet thick.

In the southwest quarter of the southwest quarter of section 20, the St. Clair limestone has a phosphatic layer at least one foot thick at its top.

On the western slope of the hill east of Polk Bayou, in the southeast quarter of section 20 are some small fragments of rock, indicating a very thin bed of the phosphate rock.

In the northwest quarter of section 14, on the southeast slope of the hill known as Davis' Hill, a layer of soft earthy phosphate rock two and one-half feet thick is exposed. The lower foot of this layer contains pebbles.

One hundred and fifty yards north of the center of the southwest quarter of section 11, 14 North, 6 West, near the head of the ravine in the manganese pits, a layer of soft yellow phosphate earth is exposed. This layer is said to be three feet thick.

Near the center of the southwest quarter of section 14 near the top of the hill on its western slope, the St. Clair limestone is phosphatic.

The Vicinity of Cushman.—We shall not attempt to mention all the sections on which phosphate rock is to be looked for in the region about Cushman, but facts enough will be given to enable one to locate the horizon readily and to find the phosphate rock if it is not concealed by soil or chert fragments. In the neighborhood of Cushman the phosphate rock is usually of a light-brown color, but is darker on a weathered surface than in a freshly broken one. This phosphate rock is common in the manganese mines, and there is no doubt that the low grade of some of the Batesville manganese ores is due to the presence of the phosphate beds in the manganese region. Everybody who has worked about the manganese mines in the neighborhood of Cushman is familiar with what the miners call "ochre." This is the phosphate rock of that region, though it does not closely resemble the same rock found on the Milligan place near Hickory Valley.

Fourteen North, seven West.—In the northeast quarter of the southwest quarter of section 15, 14 North, 7 West, in the road 100 yards west of the house of Mr. Miller (the county assessor) are large fragments of brownish, fine grained, phosphatic sandstone which indicates a thickness of two and one-half feet.

Rock of about the same character as that near Mr. Miller's occurs on the north slope of the hill a quarter of a mile east of his house; a thickness of about four feet is indicated here. Analysis of a small sample of this rock (by Davis and Lyons) gave:

Calcium phosphate ($Ca_3P_2O_8$), 41.52 per cent; Iron (Fe_2O_3), 11.15 per cent; Alumina (Al_2O_3), 3.18 per cent.

These deposits are three-fourths of a mile from the Cushman branch of the St. L. I. M. & S. Ry.

In section 27, 14 North, 7 West, 150 yards south of the water tank and 100 yards west of the railway south of "Big Spring," the foot of the eastern hill slope is covered with fragments of phosphate rock and phosphatic sandstone for some distance. The fragments here warrant the conclusion that the combined beds have a thickness of about eight feet. Mining at this place would necessarily be by drifting.

One mile north of Cushman, a quarter of a mile east of the Grubb Cut, and a quarter of a mile south of the Polk Southard mine, phosphate fragments cover the top of the hill, at the south side of the road, for a distance, east and west, of 150 yards. Fragments of the rock are found also on the north slope of the hill running east from this deposit. Mining by stripping could be carried on with ease here, inasmuch as there would be very little top soil to remove. This deposit is at a higher elevation than Cushman. The roads in the immediate vicinity are good.

On the north slope of the hill immediately southeast of the Phelp's Spring large blocks of phosphate rock and phosphatic sandstone are scattered about over the hillside. These fragments indicate a total thickness of about ten feet. This bed may be traced by its fragments, northward on the west slope of the hill for two hundred and fifty yards, and westward around the north slope of the hill for one hundred and fifty yards. The bed is exposed in an old manganese opening east of, and twenty-five feet higher than the road half way from the Phelp's Spring Club House to the top of the hill toward Cushman. This deposit is within a quarter of a mile of Cushman.

About three-quarters of a mile south of Cushman, on the wagon road to Batesville, phosphatic sandstone (the Sylamore sandstone) with some manganese is exposed in the road. It is here between 10 and 20 feet thick, judging from the fragments to be seen. The Sylamore sandstone is probably exposed at this elevation on account of a low anticlinal fold, which fold should be kept in mind in the further search for the mineral in this locality.

In 14 North, 7 West, section 8, the southwest quarter of the northwest quarter, fragments of the phosphate rock and the underlying sandstone cover the hillside nearly opposite Farrell's Cave. The underlying sandstone (Sylamore sandstone) here proably rests upon the St. Clair marble bed.

This deposit is one and a quarter miles from Cushman, and at a higher elevation than that place. A good wagon road or a railroad could be constructed with comparative ease from the deposit to Cushman.

Loose fragments of phosphate rock are scattered for some distance along the brow of the hill and also cover the top of the point of the ridge at the west end of the Jim Martin field. Analysis (by Davis and Lyons) of loose fragments from the Jim Martin field gave 46.72 per cent of calcium phosphate ($Ca_3 P_2 O_8$). Over a limited area the rock here could be removed with but little stripping of the overburden. Most of the rock from this locality however, would be obtained by drifting.

Figure 3 shows a section of the phosphate rock on the south slope of the hill near the easternmost exposure of phosphate rock in the southwest quarter of the northwest quarter of section 8. At this point there is a considerable overburden of chert and mining would have to be done by drifting.

The following section is exposed at a prospect pit on the south slope of the hill:

Bed No. 1, Chert fragments and debris to the top of the hill.
" " 2, Eight inches of siliceous and phosphatic shale, weathering brown.
" " 3, Nine inches of light bluish gray phosphate rock, rather fine grained with some very small pebbles.
" " 3a, Four and one-half inches of green siliceous phosphatic shale, with some phosphate nodules.
" " 4, Thirty-two inches of fine grained phosphate rock, brown in color.
" " 5, Twelve inches of brown phosphate rock with small nodules.
" " 6, Six inches of apparently low grade phosphate rock, merging into sandstone in its lower portion.
" " 7, Five feet bluish-green, hard, fine grained sandstone, weathering to light brown.

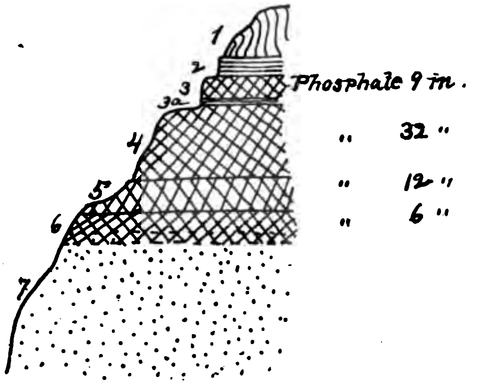

Fig. 3. Section of phosphate beds exposed in a pit in the southwest quarter of the northwest quarter of section 8, 14 North, 7 West.

Analyses of rock from the section shown in Fig. 3.

J. Ross Hanahan and Davis & Lyons, Analysts.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Average sample of beds No. 3, 4, 5......	34.13	.....
" " " " " 3, 4, 5......	44.79	.....
" " " " " 3	50.79	11.68
" " " " " 4	48.53	.....
" " " " " 5	44.45	.....
Fragments from the west end of the old field	46.72	.....
Fragments from the west end of the old field*	52.51	17.02
(a) Unweathered fragment of sandstone (bed No. 7), contains some calcium carbonate	6.48	.....
(b) Partially weathered rock from the same large block that (a) was taken from	.87	.....
(c) Weathered brown sandstone from outside of same large block from which (a) and (b) were taken.....	1.05	.....

*Davis & Lyons analysts. The other analyses are by Hanahan. Analyses of two samples of rock from this locality made by the Ledoux Chemical Co., of New York, showed 62.47 per cent and 67.40 per cent, respectively, of calcium phosphate.

The samples from which Analyses a, b, and c of the above table were made, were taken from a very large fragment of the fine grained Sylamore sandstone (bed No. 7, Fig. 3). This fragment was blasted open and showed a gradation in color from the outer highly weathered portion of the surface (from which (c) was taken), through less weathered brownish rings towards the center (from which (b) was taken), to the bluish and apparently little weathered portion near the center (from which (a) was taken). The analyses indicate that the unweathered rock is quite phosphatic, while the portions exposed to the weather are less so, probably because the phosphoric acid has been leached out from these weathered portions. The higher percentage of calcium phosphate shown in *c* than in *b* may be due to improper sampling, or to the deposition (on the outer portion of the rock) of phosphoric acid, leached from the overlying phosphate beds and here re-deposited.

The area underlain by the rock at this locality is about 40 acres. The total thickness of the phosphate rock which could be mined as exposed in the pit on the south slope of the hill (fig. 3) is 53 inches; taking four feet as an average thickness, the tract contains about four hundred and sixty-four thousand (464,000) tons of rock.

About half a mile west of Cushman, on what is known as the Meeker place (14 North, 7 West, Sec. 8), the phosphate bed is exposed in an old manganese pit on the north slope of the hill, and from this point may be traced westward, along the north face of the hills, for two and one-half or three miles. It always overlies the marble, and, as the rocks are horizontal, the position of the bed is easily determined, even when it is concealed, as it is for the most part. Along the contour followed by the phosphate beds, a good many pits have been dug in search of manganese, and in these pits the phosphate beds are almost always uncovered.

The section in one of the pits on the Meeker place is as follows, beginning above:

Soil at the top:	
Black phosphate rock	2.5 feet.
Manganese ore	1 to 3 inches.
Marble	3 feet.

This exposure is about 50 feet in length.

Another one of tnese pits has—

Soil at the top:	Feet.
Chert	3
Phosphate-rock	3.5
Iron and manganese	2
Concealed	2
Marble	3

A third pit has—

Soil at the top:	Inches.
Phosphate-rock exposed	18
Iron and manganese	8
Marble	?

A fourth pit has—

Chert fragments and soil at the top:	
Phosphate-rock	3.5 feet.
Manganese, iron and phosphate-rock	3
Underlying rock	not seen.

Analyses of rock from the Meeker place:

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
*Average sample	49.38	8.82
*An unweathered fragment	27.46	13.15

Hightower's.—The phosphate bed may be traced by its fragments (which indicate a considerable thickness) from the southwest quarter of section 12, 14 North, 8 West, along the south slope of the ridge to the head of the valley northeast of W. M. Hightower's house, at the north one-half mile corner of section 18, 14 North, 7 West.

*Davis & Lyons, analysts.

About a quarter of a mile north from Mr. Hightower's house, near a sink hole, the south slope of the hill is covered with phosphate and Sylamore sandstone fragments. The fragments at this place warrant the conclusion that the combined beds have here a thickness of at least ten feet. Analysis* of this rock gave the following result:

Calcium phosphate ($Ca_3P_2O_8$), 38.60 per cent; Alumina (Al_2O_3), 5.30 per cent; Iron (Fe_2O_3), 9.50 per cent.

Fragments of the rock are scattered over Mr. Hightower's field a quarter of a mile west of his house, and the bed may be traced by its fragments westward along the north slope of the ridge to a point just southeast of the junction of East and West Lafferty Creeks, where it passes beneath the surface. The nearest point of this locality to Cushman is two miles, and the remotest is four miles. The nearest point to White River is one mile, and the remotest is three and one-half miles.

From the vicinity of Ferrell's Cave the phosphate horizon passes westward through sections 8 and 7, and enters 14 North, 8 West, at the center of the east line of section 12. Phosphatic fragments are exposed at many points along this line through sections 8 and 7.

14 *and* 15 *North*, 8 *West*.—Rock of the same general character as the Cushman phosphate beds occurs at several other places west of Cushman, notably at the following: 14 North, 8 West, section 12, middle of the section; along the north side of the valley, in the south half of the section; along the south side of the valley through the north side of section 13; section 14 along the south side of the valley of East Lafferty Creek; section 11, south half, about the head of the hollow draining into West Lafferty Creek; sections 15 and 10, on the west isde of the valley sloping toward West Lafferty Creek; section 9, at Penter's Bluff, in the northeast corner of the section on the side of the hill sloping toward White River. The rock, however, is harder in this section of the country than that in the Lafferty Creek valley, where it is soft and yellow.

The phosphate bed should be looked for at the top of the St. Clair marble bed wherever that bed occurs throughout the three northern tiers of sections in 14 North, 8 West, and in 15 North, 8 West. It should also be sought at the base of the Boone chert where it rests upon the Izard limestone. The phosphate horizon extends up West Lafferty Creek from the mouth of East Lafferty Creek to Lee's Mountain, in section 7, 15 North, 8 West, winding in and out about the head

*Davis & Lyons, analysts.

waters of the tributaries entering that stream from the west, and also on the east side as far north as the southwest quarter of section 35, 15 North, 8 West.

In 15 North, 8 West, section 29, northwest quarter, are many loose boulders of the phosphate rock. It is here of a dark brown color or even black, and is earthy and soft, and the bed seems to be only about a foot in thickness.

This horizon follows up the north side of White River from the northwest quarter of section 15, 14 North, 8 West, swinging around the heads of all hollows, and, on Wilson Creek, reaching as far north as the southeast quarter of section 18, 15 North, 8 West. West of this stream it comes close to White River, at a number of places, but it ascends several valleys both small and large, notably those of Campbell Branch, Cedar Branch, Rocky Bayou, Hidden Creek and Lyon's Creek. West of this last stream it is not known on the north side of White River east of Shipp's Ferry.

The thickness, character and relations of the rock in 14 and 15 North, 8 West are shown by the sections and analyses given below.

Near the center of the southwest quarter of the southwest quarter of section 12, 14 North, 8 West, the phosphate rock is exposed at the top of a small outlying point. A prospect pit (number 11, fig. 5) here exposed the following section (fig. 4).

Bed No. 1, Twelve inches of phosphate rock at the top of the hill, with no overburden.
" " 2, Twelve inches of phosphate rock.
" " 3, Phosphatic sandstone at the bottom of the pit.

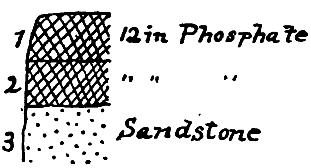

Fig. 4. Section of pit near the center of the southwest quarter of the southwest quarter of section 12, 14 North, 8 West.

Analyses of beds shown in Fig. 4.

J. Ross Hanahan and Davis and Lyons, Analysts.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
General sample	58.31	5.85
Average sample of bed No. 1	33.57	.....
" " " " 2	55.98	.....
*Sample from surface fragments	33.21	14.21

*Davis & Lyons, analysts. The other analyses are by Hanahan.

There are about seven hundred tons of phosphate rock on the point on which the pit was sunk. Similar rock occurs also in the hill east of this point. A fair mountain road runs from the east side of section 12 to Cushman, which is three and one-half miles distant.

There are many outcrops of phosphate rock in the hills on the south side of the valley in the northwest quarter of section 13 and the north half of section 14. The outcrops here are from 100 to 250 feet above the valleys. A railway up the east side of White River and up Lafferty Creek has lately been built to reach this locality.

The locations of the pits at which the sections (shown by Figs. 4, and 6 to 15 inclusive) are exposed are shown on Fig. 5.

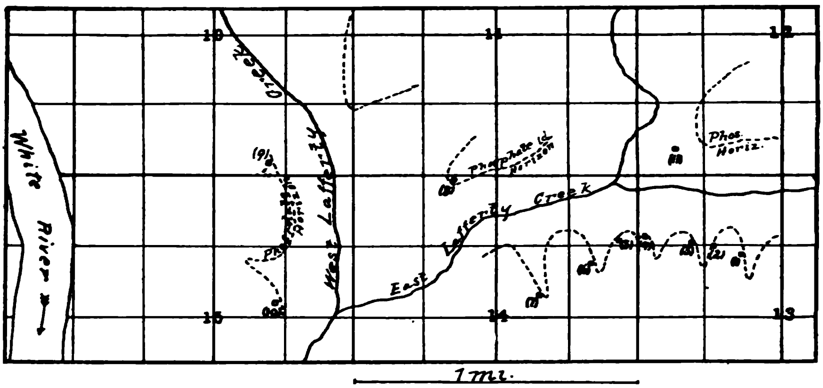

Fig 5. A map of portions of sections 9, 10, 11, 12, 13, 14, 15 and 16, 14 North, 8 West, showing the approximate locations of the phosphate horizon and the prospect pits at which the sections shown in Fig. 4, and Figs. 6 to 15 inclusive, are exposed. The numbers in brackets refer to the prospect pits, as referred to in the sections. The broken-line shows the phosphate horizon.

The following section is exposed at pit No. 1 in the southeast quarter of the northwest quarter of section 13, township 14 North, 8 West. (Fig. 6):

Bed No. 0, Chert debris and clay at top of pit.
" " 1, Three inches of yellow siliceous clayey shale.
" " 2, Thirteen inches of brown, fine grained phosphate rock with some very small nodules.
" " 3, Fourteen inches of yellowish shale, siliceous and apparently slightly phosphatic.
" " 4, Nine inches of bluish black phosphate rock, with some pyrites finely disseminated through it.
" " 5, Thirty inches of fine grained, soft, brownish phospnate rock with some very small nodules.
" " 6, Six inches of bluish black, hard, fine grained phosphate rock.
" " 7, Ten inches of soft, brown, fine grained phosphate rock.
" " 8, Phosphatic sandstone to bottom of the pit.

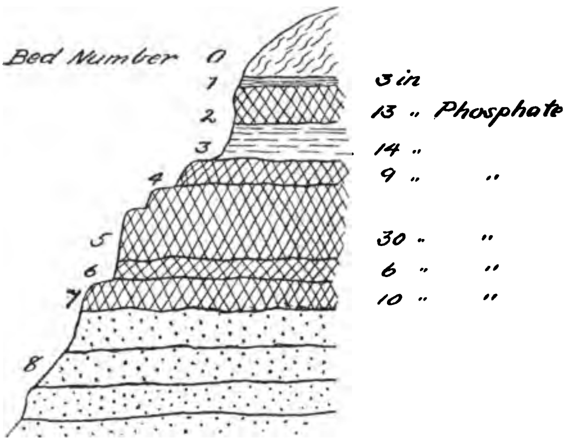

Fig. 6. Section exposed in pit No. 1 in the southeast quarter of the northwest quarter of section 13, ownship 14 North, 8 West.

Analyses of beds shown in Fig 6.

J. Ross Hanahan, Analyst.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Average sample of bed No. 2	39.65	.....
" " " " " 4	41.27	.....
" " " " " 5	55.27	8.33
" " " " " 6	50.67	8.52
" " " " " 7	50.66	9.97

The following section is exposed at pit No. 2, near the northwest corner of the southeast quarter of the northwest quarter of section 13. (Fig. 7.)

Bed No. 0, Chert debris at top of pit.
" " 1, Two-inch phosphatic layer.
" " 2, Twenty-four inches of more or less phosphatic shale.
" " 3, One foot of hard bluish gray phosphatic rock.
" " 4, Twenty-four inches of soft, brown phosphatic rock.
" " 5, Thirty inches of soft, very brown phosphate rock, heavily stained with iron oxide.
" " 6, Three feet of brown phosphatic sandstone.
" " 7, Six feet of fissile clayey and siliceous, dark shale.
" " 8, Ten inches of greenish shale (filled with phosphate nodules) with a bottom layer of close grained rock one inch thick (Bed No. 9).
" " 10, St. Clair marble.

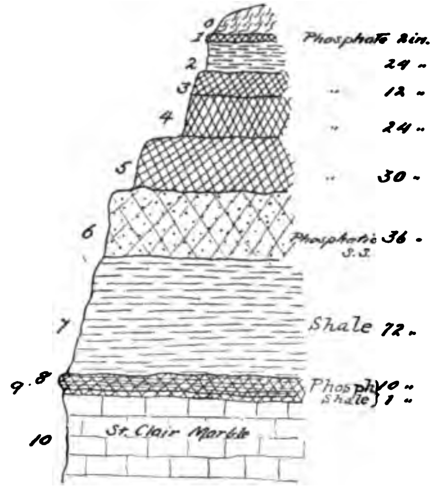

Fig. 7. Section of pit No. 2, near the northwest corner of the southeast quarter of the northwest quarter of Section 13, township 14 North, 8 West.

This section is of particular interest as it shows the interval between the St. Clair marble and the Boone Chert, although the chert overlying bed No. 1 was not seen in place.

Analyses of beds shown in Fig. 7.

J. Ross Hanahan, Analyst.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Average sample of bed No. 3	15.47	.....
" " " " " 4	57.98	10.52
" " " " " 5	36.54	.....
" " " " " 8	29.43	.....

The following section is exposed in pit No. 3. (Fig. 8):

Bed No. 0, Chert at the top of the pit.
" " 1, Eight inches of clay shale.
" " 2, Twenty-one inches of phosphate rock.
" " 3, Phosphatic sandstone at the bottom of the pit.

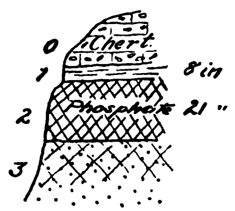

Fig. 8. Section of pit No. 3 just west of the center of the northwest quarter of Section 13 Township 14 North, 8 West.

Analysis* of bed No. 2 showed it to contain calcium phosphate ($Ca_3P_2O_8$), 51.49 per cent, and iron alumina (Fe_2O_3 and Al_2O_3), 7.57 per cent.

*J. Ross Hanahan, analyst.

The following section is exposed at pit No. 4 in the northwest quarter of the northwest quarter of section 13, township 14 North, 9 West. (Fig. 9):

Bed No. 1, Debris at the top of the pit.
" " 2, Twelve inches of brown phosphate rock.
" " 3, Phosphatic sandstone at the bottom of the pit.

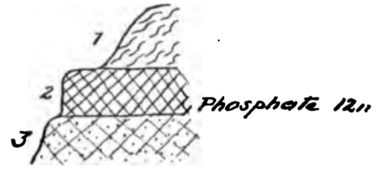

Fig. 9. Section of pit number four in the northwest quarter of the northwest quarter of section 13, Township 14 North, 8 West.

An analysis* of bed No. 2 shows it to contain: Calcium Phosphate ($Ca_3P_2O_8$), 54.93 per cent; Alumina and Iron (Al_2O_3 Fe_2O_3), 8.96 per cent.

The following section is exposed in pit No. 5. (Fig. 10):

Bed No. 1, Debris at the top of the pit.
" " 2, Eighteen inches of dark brown phosphate rock.
" " 3, Three inches of siliceous material with phosphatic nodules as large as hazelnuts.
" " 4, Phosphatic sandstone at the bottom of the pit.

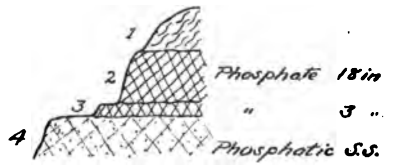

Fig. 10. Section exposed in pit number five in the northeast quarter of the northeast quarter of section 14, 14 North, 8 West.

Analyses of phosphate rock at the pit shown in Fig. 10.

J. Ross Hanahan, Analyst.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 2	68.72	8.31
" " 2 after crushing and washing	68.45	.....

The following section is exposed at pit No. 6 in the southeast quarter of the northeast quarter of section 14, 14 North, 8 West. (Fig. 11.)

*J. Ross Hanahan, Analyst.

Bed No. 1, Debris and chert fragments at the top of the pit.
" " 1a, Four inches of greenish, siliceous phosphatic shale.
" " 2, Ten inches of brown, soft phosphate rock.
" " 3, Eighteen inches of hard, fine grained siliceous rock.
" " 3a, Three inch layer of iron stained chert.
" " 4, Eighteen inches of greenish phosphatic rock, quite sandy in its upper portion.
" " 5, Ten inches of soft coarsely granular, brown phosphatic rock.
" " 6, Fourteen inches of dark brown, coarse grained phosphate.
" " 7, Siliceous shale at the bottom of pit, deeply stained with iron oxide.

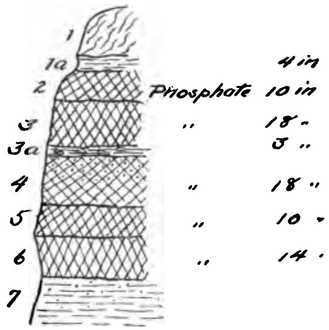

Fig. 11. Section of pit number six in the southeast quarter of the northeast quarter of section 14, 14 North, 8 West.

Analyses of rock from pit No. 6.

J. Ross Hanahan, Analyst.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 2	57.39	9.80
" " 4	48.42	.....
" " 5	15.76	15.66
" " 6 (bottom layer)	44.25	.....

The following section is exposed in pit No. 7 in Pine Hollow in the southwest quarter of the northeast quarter of section 14, township 14 North, 8 West. (Fig. 12).

Bed No. 1, Clay and debris in the head of the pit.
" " 2, Two inches of soft brown sandstone.
" " 3, Sixteen inches of dark brown nodular phosphate rock.
" " 4, Eight inches green phosphatic shale.
" " 5, Brown shaly phosphatic sandstone at the bottom of the pit.

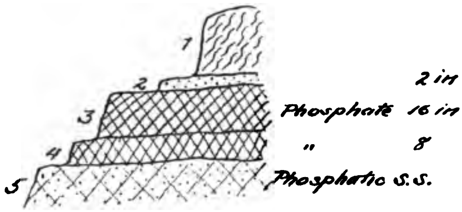

Fig. 12. Section exposed in pit number seven in Pine Hollow in the southwest quarter of the northeast quarter of section 14, 14 North, 8 West.

Analyses of rock from pit No. 7.

J. Ross Hanahan and Davis and Lyons, Analysts.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 3	68.22	4.98
" " 3 (Calcined)	69.02	4.92
*Surface fragments	51.65	6.03

A large area is underlain by the phosphate rock in sections 13 and 14. The average thickness as indicated by the rock exposed in the sections shown in Figs. 6-12 is about two and one-half feet. The variation in thickness is from 1 foot to 5 feet 10 inches.

The phosphate horizon occurs in the hilltops in the southwest quarter of section 11, on the east side of West Lafferty Creek. At the point of the hill near the south line of the southwest quarter of section 11 the following section is exposed:

The following section is exposed in pit No. 8, near the south side of the southwest quarter of section 11 (Fig. 13):

Bed No. 1, Debris at the head of the pit
" " 2, Three inches of clay shale.
" " 3, Six-inch bed of very dark phosphate rock.
" " 4, Three inches of black shale.
" " 5, Eight inches of hard brown phosphate.
" " 6, Four inches of compact black phosphate.
" " 7, Eleven inches of shaly sandstone.
" " 8, Eleven inches of soft, brown phosphate rock.
" " 9, Two feet of shale underlying the phosphate bed.

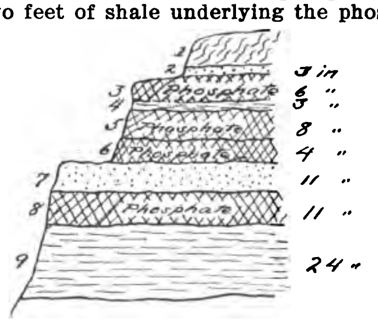

Fig. 13. Section exposed in pit number eight, near the south line of the southwest quarter of section 11, 14 North, 8 West.

*Davis & Lyons, Analysts. The other analyses are by Hanahan.

Analyses of rock from pit No. 8.

J. Ross Hanahan and Davis and Lyons, Analysts.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 3	62.70	8.74
" " 5	60.07	7.38
" " 8	47.19	.....
*Surface fragments	56.81	8.97

The over-burden is such that mining at this locality would necessarily be by drifting.

The following section is exposed in pit No. 9 in the southwest quarter of the southeast quarter of section 10, 14 North, 8 West. (Fig. 14):

Bed No. 1, About five feet of soil and debris at the top of the hill.
" " 2, One foot of hard-pan.
" " 3, Three inches of clay shale.
" " 4, Six inches of brown, soft pebbly phosphate rock.
" " 5, Six inches of yellowish, fine grained sandstone.
" " 6, Twenty-two inches of fine grained and fine nobular phosphate rock, dark colored.
" " 7, Greenish, fine grained phosphatic sandstone.

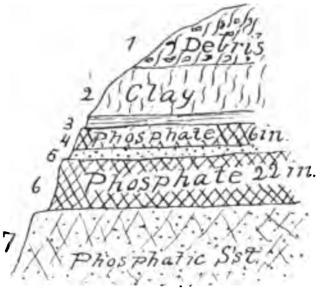

Fig. 14. Section of pit number nine, at the top of the ridge west of Henry Collie's house in the southwest quarter of the southeast quarter of section 10, 14 North, 8 West.

Analyses of the phosphate rock at pit No. 9.

J. Ross Hanahan and Davis and Lyons, Analysts.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 6	41.85	.....
" " 6 (top layer)	43.16	.....
" " 6 (bottom layer)	50.14	.....
*Average sample of bed No. 3	44.54	21.84

*Davis & Lyons, Analysts. The other analyses are by Hanahan.

The following is exposed in pit No. 10, near the center of the east half of section 15. (Fig. 15):

Bed No. 1, Red clay with chert fragments at the head of pit.
" " 2, Twenty-seven inches of dark brown nodular phosphate rock.
" " 3, Five inches of brown, iron stained nodular phosphate rock.
" " 4, Five inches of red iron stained material with phosphate nodules.
" " 5, Three feet of greenish, fine grained phosphatic sandstone.

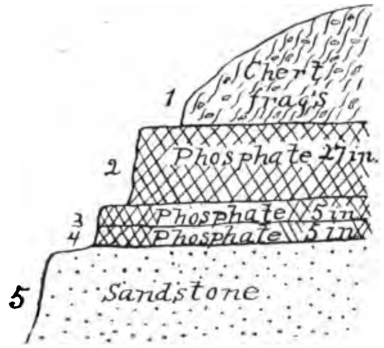

Fig. 15. Section exposed in pit number ten, near the center of the east half of section 15 14 North, 8 West.

Analyses of phosphate from pit No. 10.

J. Ross Hanahan and Davis and Lyons, Analysts.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 2	70.40	7.03
*Beds 2 to 5, inclusive	59.55	15.05

*Davis & Lyons, analysts. The other analysis is by Hanahan.

The phosphate rock crops out near the top of the hills in the northeast quarter, and the north half of the southeast quarter of section 4, township 14 North, 8 West. The rock is here about one mile from White River, and 450 feet higher than that stream. A portion of the rock in this locality could be mined by stripping; the larger part of it, however, would necessarily be mined by drifting, as the overburden is too thick to be removed. The overlying rock, except near the edges of the outcrop where it has been weathered away, is massive and would make good roof.

The following section is exposed in a prospect pit in the northwest quarter of the southeast quarter of section 4 (Fig. 16), 14 North, 8 West.

Bed No. 1, Red clay at the top of the pit
" " 2, Four inches of clayey shale.
" " 3, One and a half inches of green shaly phosphate rock.
" " 4, Twelve inches of hard, nodular phosphate rock
" " 5, Eight inches of green sandy phosphate rock.
" " 6, Shaly phosphatic sandstone.

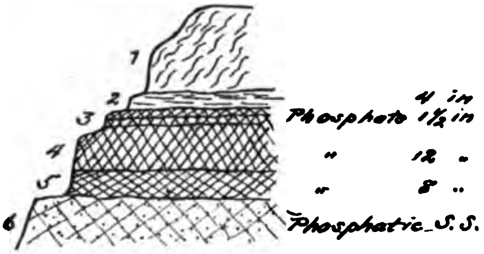

Fig. 16. Section exposed at a prospect pit in the northwest quarter of the southeast quarter of section 4, 14 North, 8 West, southwest of Tom Tate's field.

Analyses of rock from the prospect pit shown in Fig. 16.

J. Ross Hanahan and Davis and Lyons, Analysts.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 4	58.27	5.79
" " 5	55.57	6.18
*Average sample of surface fragments..	63.72	13.80

The following section is exposed in a prospect pit near the center of the northeast quarter of section 4. (Fig. 17).

Bed No. 1, Overburden of stiff red clay.
" " 2, Ten inches of clay shale.
" " 3, Six inches of shaly sandstone.
" " 4, Ten inches of phosphatic sandstone.
" " 5, Twelve inches of phosphate rock.
" " 6. Greenish phosphatic sandstone.

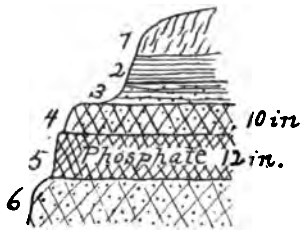

Fig. 17. Section exposed in a prospect pit near the center of the northeast quarter of section 4, township 14 North, 8 West, west of Tom Tate's field.

Analyses of phosphate rock from the pit shown in Fig. 17.

J. Ross Hanahan and Davis and Lyons, Analysts.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 5	66.39	4.13
*Surface fragments	48.32	14.47

*Davis & Lyons, analysts. The other analyses are by Hanahan.

The following is exposed in a prospect pit near the north side of the northeast quarter of section 4, west of Tom Tate's field.

Bed No. 1, Eight feet of clay overburden.
" " 2, Three inches of shale.
" " 3, Fourteen inches of brown phosphate rock, with many nodules.
" " 4, Fine grained phosphatic sandstone at the bottom of the pit.

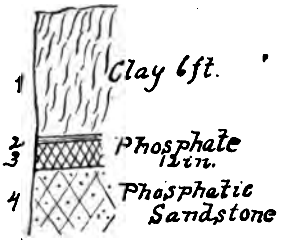

Fig. 18. Section exposed at a prospect pit near the north side of the northeast quarter of section 4, 14 North, 8 West, west of Tom Tate's field.

Analysis of the rock from the section shown in Fig. 18.

J. Ross Hanahan, Analyst.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 3	62.05	7.18

Fragments of phosphate rock occur at the top of the point, near the center of the south half of section 4, 14 North, 8 West, within a quarter of a mile of White River. Analysis (Davis and Lyons, analysts) of this rock show it to contain calcium phosphate ($Ca_3 P_2 O_8$), 55.19 per cent; iron and alumina ($Fe_2 O_3$ and $Al_2 O_3$), 11.23 per cent.

The phosphate rock occurs in the high ridges in sections 5 and 6, 14 North, 8 West, on the north side of White River. The underlying phosphatic (Sylamore) sandstone is here quite massive, while the phosphate beds are thinner than they are in the East Lafferty Creek region. The following sections, Figs. 19 to 23, show the relations of the beds in this region.

Along the west slope of the hill through the northeast quarter of section 5, 14 North, 8 West, and the southeast quarter of section 32, 15 North, 8 West, the phosphate bed may be easily traced by the surface fragments. Analysis (Davis and Lyons, analysts) of these fragments gave the following results: calcium phosphate ($Ca_3 P_2 O_8$), 35.25 per cent; iron and alumina ($Fe_2 O_3$ and $Al_2 O_3$), 23.32 per cent.

The following is exposed at a prospect pit on the south slope of the hill in the southwest quarter of section 5, township 14 North, 8 West. (Fig. 19).

Bed No. 1, Chert debris.
" " 2, Thin bed of limestone.
" " 3, Thin bed of sandstone.
" " 4, Thin bed of shale.
" " 4a, Sandstone.
" " 5, Nine inches of sandstone apparently phosphatic.
" " 6, Ten inches of phosphatic sandstone.
" " 7, Eighteen inches of clay.
" " 8, Limestone.

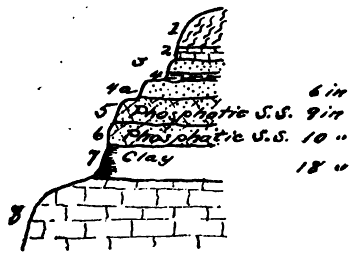

Fig. 19. Section exposed at a prospect pit at the south point of the hill in the northwest quarter of the southwest quarter of section 5, 14 North, 8 West.

Analysis of rock from the section shown in Fig 19.

J. Ross Hanahan and Davis and Lyons, Analysts.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Beds 5 and 6..........................	3.27	.....
*Surface fragments, near pit...........	67.53	7.71

The following section is exposed at a prospect pit near the center of the northwest quarter of section 5. (Fig. 20).

Bed No. 1, Compact limestone above the pit, St. Joe marble.
" " 2, Five feet of debris.
" " 3, Hard-pan.
" " 4, Clay.
" " 5, Clay.
" " 5a, Ten inches of shale.
" " 5b, Four inches of green phosphate rock.
" " 6, Very low grade phosphatic sandstone at bottom of pit.

*Davis & Lyons, Analysts.

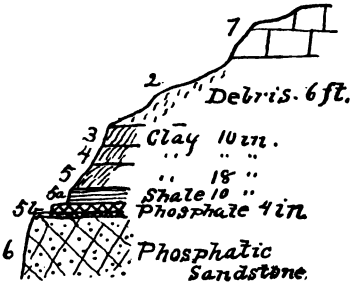

Fig. 20. Section exposed at a prospect pit near the center of the northwest quarter of section 5, 14 North, 8 West.

Analyses of rock from the section shown in Fig. 20.

J. Ross Hanahan, Analyst.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 5b	59.68	6.73
" " 6	36.04	.....
" " 4 and 5	trace.	

The following section is exposed at a prospect pit near the north line of the northwest quarter of section 5, 14 North, 8 West. (Fig. 21).

Bed No. 0, Debris and chert fragments on the hill slope.
" " 1, Five feet of compact limestone.
" " 2, Three feet of clay in the head of the pit.
" " 3, Eighteen inches of black soft sandy rock.
" " 4, Three and a half feet of close grained, brown phosphatic sandstone.

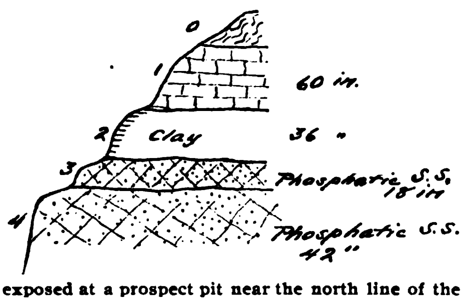

Fig. 21. Section exposed at a prospect pit near the north line of the northwest quarter of section 5, 14 North, 8 West.

Analyses of the rock from the section shown in Fig. 21.

J. Ross Hanahan, Analyst.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 3	32.94	.....
" " 4	10.23	.....

On the west slope of the hill east of Wilson Creek in the northeast quarter of the southeast quarter of section 6 the following section is exposed at a prospect pit. (Fig. 22).

Bed No. 1, Clay at the head of the pit.
" " 2, Two inches of clayey shale.
" " 3, Four and a half feet of phosphatic sandstone.
" " 4, Ten inches of reddish phosphate rock with small nodules.
" " 5, Three feet of shale in the bottom of the pit.

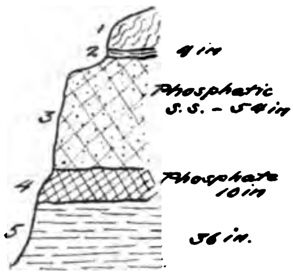

Fig. 22. Section exposed at a prospect pit in the northeast quarter of the southeast quarter of section 6, 14 North, 8 West.

Analyses of rock from section shown in Fig. 22.

J. Ross Hanahan, Analyst.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 3	28.01	.....
" " 4	37.36	.....
*Surface fragments	48.27	8.61

At the south point of the high ridge, near the center of section 6 the following section is exposed at a prospect pit. (Fig. 23).

Bed No. 1, Hard crystalline limestone.
" " 2, Ten inches of clay and shale.
" " 3, One foot of hard siliceous phosphate rock.
" " 4, Two and a half feet of shale.

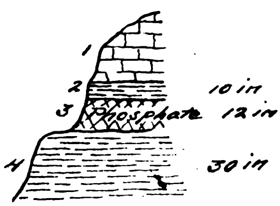

Fig. 23. Section exposed at a prospect pit on the south point of the high ridge near the center of section 6, 14 North, 8 West.

*Davis & Lyons, analysts. The other analyses are by Hanahan.

Analysis of phosphate rock shown in Fig. 23.

J. Ross Hanahan, Analyst.

	Calcium Phosphate. ($Ca_3P_2O_8$) Per Cent.	Iron & Alumina. (Fe_2O_3 and Al_2O_3) Per Cent.
Bed No. 3	26.16	.....

The phosphatic sandstones (Sylamore sandstone) in the vicinity of Wilson Creek is fine grained and hard, and can be easily traced, by its large surface fragments along the hillsides. The softer phosphate beds of this locality, which are similar to those of the Lafferty Creek region, are not thick enough, however, where they have been observed, to be of commercial importance.

In the southwest quarter of the southeast quarter of section 31, 15 North, 8 West, the phosphate bed is underlain by a phosphatic limestone, an analysis of which gave the following results (Davis and Lyons, analysts,): Calcium phosphate (Ca_3 P_2 O_8), 17.33 per cent; iron and alumina (Fe_2 O_3 and Al_2 O_3), 29.72 per cent.

An analysis of fragments of conglomeritic phosphate rock from the east slope of the ridge near the center of the southwest quarter of section 30, 15 North, 8 West, gave the following result (Davis and Lyons, analysts,): Calcium phosphate (Ca_3 P_2 O_8), 40.93 per cent; iron and alumina (Fe_2 O_3 and Al_2 O_3), 8.69 per cent.

Fourteen North, Nine West, North of White River.—In the northeast quarter of section 1, 14 North, 9 West, the phosphate bed is exposed in a small gully which opens out westward to White River. The phosphate bed is about two feet thick at this place. It is heavily stained with iron oxide and rests directly upon the St. Clair marble, which itself contains many small phosphate nodules at its top.

South of White River.—South of White River the horizon of the phosphate rock begins at the river bank about two miles above Wall's Ferry. From this point it follows along the south side of that stream, in some places coming close to the water, in others swinging away south around the heads of hollows and streams, such as Cagen Creek, Dry Creek, Rocky Bayou and Hell Creek. Along these several streams as far west as the mouth of Sylamore Creek, the total length of the phosphate horizon is about sixty-five miles.

In 14 North, 9 West, section 3, 300 yards northeast of John Greenway's house the rocks are exposed in the following order:

	Feet.
St. Joe marble	8
Light green siliceous rock	2
Concealed	3
St. Clair marble	10

We take the green rock of this section to be the phosphate bed, which, at this place, on account of the underlying rock being concealed, may have a greater thickness than is reported above.

Another exposure in the same section, on the east side of the Cagen Creek, opposite Jeff. Greenway's house, about half a mile up the creek from John Greenway's is as follows:

	Feet.
Chert	20
Limestone	1
Green shale	¼
St. Joe marble, the bottom layers containing patches of black shale, sand and black pebbles	8
Green and black shale (bottom concealed)	15

The black pebbles below the St. Joe marble here are the phosphate-layer. At the upper end of this bluff, this layer is, in places, 8 inches thick.

In 15 North, 9 West, section 32, on the north side of Dry Creek a bed of nodular phosphate rock overlies the St. Clair marble; and again in 15 North, 10 West, section 22, west side of Little Rocky Bayou, at the same horizon is a bed of sandstone containing black nodules of phosphate rock.

South Sylamore.—The next region in which the phosphate bed has been observed is along South Sylamore Creek and its affluents.

On Roasting Ear Creek at Norman's, in 15 North, 13 West, section 1, the phosphate bed containing black nodules is exposed between the St. Joe marble above and the St. Clair marble below.

On the west side of Sylamore Creek, opposite the mouth of South Sylamore, the limestone below is exposed to within three feet of the Boone chert, and the space between is concealed by debris. In the stream bed below, however, are fragments of Sylamore sandstone containing phosphate nodules. These fragments must have come from the horizon here concealed. The bed, however, is necessarily but thin at this particular place. Search should be made at this horizon along both sides of this stream for local thickening and enrichment of the phosphate rock.

Mention can here be made of only a few points at which we have seen the rocks occupying this horizen. It should not be forgotten, however, that while none of the deposits thus far examined on Sylamore Creek seem to be of an economic importance, this fact should not prevent more careful search for such beds along this stream and on both sides of it and of its tributaries.

At the little school-house near the mouth of Lick Fork, the contact between the Silurian and the Lower Carboniferous rocks is exposed

in the rear of the building on the side of the hill near the creek. The bed between them is about 18 inches thick, the upper part of which is sandy and contains black phosphatic nodules and the lower half decays to a soft earth, resembling the Cushman phosphate beds.

On the south side of Sylamore Creek, about half a mile below the mouth of Lick Fork, there is a similar concretionary bed one foot or more in thickness, between the St. Clair and the St. Joe marbles. The phosphate rock at this place is of a dirty brown color.

On the west side of Sylamore Creek and south of Dry Creek, the Sylamore sandstone seems to have a thickness of about 15 feet, 6 feet of which is well exposed at one place high on the side of the hill. The rock at this place is chiefly a rather coarse-grained, hard sandstone, almost a quartzite. There are some layers two or three inches thick that are rich in phosphate nodules, but most of the bed is poor.

In 15 North, 11 West, section 21, in the hill southeast of Prater's, the base of the Sylamore sandstone is about 100 feet above the stream and it seems to have a thickness of 30 or 40 feet. It is hard and compact where examined, however, and the phosphate nodules are not abundant.

In 16 North, 13 West, section 24, the Sylamore sandstone is exposed near the top of the hill south of Capp's Fork. Above it is the Boone chert, and below it is the Izard limestone.

North Sylamore Creek, North and West.—On the North Sylamore Creek the horizon at which the phosphate rock is to be sought lies near the top of the hills and on both sides of the creek and its tributaries from near 15 North, 11 West, section 3, to the head waters of Capp's Fork, in 16 North, 13 West, section 3, and to the head waters of Cole's Fork in 17 North, 13 West, section 23; and to the head waters of Stewart's Fork in 16 North, 12 West, section 18. The outcrops should also be examined along the sides of the valleys opening into these larger ones. The phosphate horizon in this region will be found just below the bed of pink marble that is exposed here and there well up the slopes of the hills.

Search should also be made at this same horizon along the hillsides southwest of Livingstone Creek as far west as 16 North, 12 West, section 13. From this point in a general northwest course the phosphate horizon is near the tops of the hills about the heads of the following streams: Sugar Loaf Creek, Jackson Creek, Cataract Creek, Burnt Mill Creek and Sneed's Creek.

Beginning at the head of Sneed's Creek in 17 North, 13 West, section 14, the phosphate horizon runs northeast, north and then west, following around the brow of Leatherwood Mountain.

In 17 North, 14 West, section 12 it runs out on the spur of that mountain lying between Trimble's Branch and Brush Creek. In section 13 of the same township and range it caps the spur lying between Brush Creek and Leatherwood Creek, and is not more than a mile from Buffalo Fork of White River. From this point the phosphate horizon follows the brow of Leatherwood Mountain up one side and down the other of the several tributaries of Leatherwood Creek. The outcrop about the drainage basin of this stream alone has a total length of about twenty-three miles.

North of Leatherwood Mountain and lying near White River is a series of peaks or knobs capped with the rocks that overlie the phosphate horizon, so that the phosphate rocks should be looked for near the top of these peaks. One of them is known as Matney's Knob; this is within a quarter of a mile of White River. Another is a mile due west of Matney's Knob and is about half a mile south of the river. The next one to the west is about three-quarters of a mile south of Shipp's Ferry and half a mile east of the mouth of Steep Gut. This ridge is more than a mile long and extends from the middle of the south half of section 15 to near the southwest corner of section 16, 17 North, 13 West. Another of these ridges rises on the south bank of White River between the Steep Gut and Mill Creek; it is a little more than a mile in length. West of Mill Creek and south of Nelson's Ferry is still another hill capped by Boone chert; the phosphate horizon around its brow is more than four miles long. There is one small patch of Boone chert exposed on the north side of White River about half a mile west of Shipp's Ferry; the phosphate horizon is about a mile long around this hill.

Long Creek.—On Long Creek, Searcy County, the interval between the Silurian and Lower Carboniferous rocks is occupied by a coarse-grained sandstone, containing phosphate nodules. The bed seen in 15 North, 14 West, section 14, where the road passes near it, has a thickness of only two feet; it probably has a greater thickness in this region, and careful search should be made for it. The horizon at which it is to be sought is crossed by the Mountain View-Marshall road, in 15 North, 14 West, secton 14. From this point it follows westward along both sides of the creek to near the mouth of Turkey Creek. It ascends Turkey Creek to near where that stream enters section 23, when it turns and comes down along its west side. Following up one side of the tributaries and down the other, it crosses Seller's Creek near the south side of section 21, of 15 North, 14 West, and follows the west side of the valley to near Long Creek.

From where the road up Big Creek crosses this last stream the horizon follows the western side of the valley of Long Creek for about three miles, when it swings gradually to the west and crosses the head of Hickory Hollow in 16 North, 14 West, section 30, south side. Here it turns to the southeast and follows the north side of Hickory Hollow to near Long Creek again. Between the mouth of Hickory Hollow and Turkey Pen Branch the Sylamore sandstone has been seen at several places. Along Turkey Pen Branch the phosphate horizon runs up the south side of the stream, and down the other, the outcrop on this stream being about six miles in length.

The details of the phosphate horizon north of Turkey Pen Branch cannot be given very precisely, but it may be said that it follows the general course of Big Creek winding in and out about the sides of its tributaries from the west to a point about half a mile southwest of where this stream enters Buffalo Fork.

Returning to the first exposure mentioned on Long Creek we may follow the phosphate horizon along the east side of Long Creek and of Big Creek. Cedar Creek entering Long Creek in 15 North, 14 West section 4, has several tributaries entering it from the south. The phosphate horizen follows around the head-waters of each of these tributaries, so that the total length of the outcrop along this stream is about twelve miles. North of the Cedar Creek Valley, there are several streams flowing into Big Creek from the east, the most important of which are Bear Creek, Short Creek and Spring Creek. All of these streams have the phosphate horizon along the sides of their valleys, and of the valleys of their tributaries. Spring Creek is the longest of these streams and the phosphate horizon within its drainage extends as far east as section 16, in 16 North, 13 West. Attention should be called to the fact that the St. Clair marble is not found on the east side of Big Creek further north than the head of Bear Creek. North of this place this particular marble disappears and the marble is represented by the St. Joe bed beneath which the phosphate rock should be sought.

Between the Spring Creek Valley and Leatherwood Creek are several streams heading in the flat-woods south of Leatherwood Mountain. The phosphate horizon winds in and out about the head waters of these streams with an outcrop between fifteen and twenty miles in length.

West of Adam's Mill, and lying between Spring Creek and Middle Creek, is a flat-topped hill capped with Boone chert and the St. Joe marble. The hill is about three miles long and the phosphate horizon around its brow is some eight miles in length.

South and west of Buffalo City are a few isolated patches of Boone chert resting upon Silurian rocks. It is not known certainly whether the phosphate rock is at the base of these chert beds or not, but we shall specify the localities in order that search may be made. The first and largest of these areas lies along the water-shed between Cow Creek on the east and Brush Creek and Boat Creek on the west. Its south end is at the southeast corner of section 9, 17 North, 14 West, and it extends nearly diagonally across this section and ends about on the middle of the west side of section 4 of the same township and range. The contact between the Lower Carboniferous and the Silurian rocks is on either side of the road following this crest line and from a quarter to half a mile away. The second area lies about half a mile north of the one just mentioned and upon the water-shed about the upper end of Moreland Hollow, partly in sections 3 and 4 of 17 North, 14 West, and partly in 33 and 34 of 18 North, 14 West.

There are two other similar patches on the water-shed between Cedar Creek and Warner's Creek, about three and a half miles west of Buffalo City. One of them is in section 31 and the other about the middle of the line between sections 30 and 31 of 18 North, 14 West.

Peaks Southeast of Yellville.—In the region east of Yellville and north of Buffalo Fork there are several outliers, either high hills or mountain peaks, capped with the rocks in which the phosphates are to be sought. What is known as Hall's Mountain, about three and a half miles southeast of Yellville, is made up of a group of three such peaks. The tops of these mountain peaks are capped with Boone chert, and beneath the chert is a bed of pink St. Joe marble; it is just below this marble the phosphate is to be expected if it is found in place. The outcrop of the phosphate horizon about these three peaks has a total length of about thirteen miles. To the south of this group, on the line between sections 24 and 25 of 18 North, 16 West, is a well known peak called Bald Jesse. This mountain is likewise capped with Boone chert and St. Joe marble, below which the phosphate rock is to be sought. This horizon is to be found also near the top of a mountain in section 20, 18 North, 15 West. Mt. Ephriam in the southern part of section 29 (18 N., 15 W.) is capped by the St. Joe marble bed, so that the phosphate bed is to be looked for very near the summit and around the mountain's brow.

The Phosphate Horizon From the Narrows to the Mouth of Spring Creek.—In the region known as "The Narrows," in 17 North, 15

West, section 13 (or 24), in the west side of the road leading from Rush post-office to Big Creek, there is a nodular sandstone, lying be-ween the St. Joe marble above and the Izard limestone below. This bed is only two or three inches thick at this place. About 200 yards south of this section, about two feet of the bottom layers of the red St. Joe marble contains black phosphate pebbles.

This phosphate rock should be looked for along the brow of the hill northwest of this place through section 14 to very close to the middle of the west side; from this place it turns and bears northeast till it touches the north line of the section, then it turns toward the southeast and approaches Buffalo Fork at the middle of section 13.

Following the horizon of the phosphate rock up the east side of Buffalo Fork, its course is very crooked; from "The Narrows" this horizon follows the brow of the hill southward through section 24 (17 N., 15 W.), crosses into the southeast corner of section 23, swings south and east across the northeast corner of section 26, follows up a tributary entering Ingram Creek from the north and crosses the head of this stream at the southeast corner of section 25. From this point it follows along the south side of Ingram Creek through the south part of sections 25 and 26, then swings south, and cuts across the southeast corner of section 27, swings further south and east and passing sections 35 and 36 follows up the north side of the valley of Hickory Creek. In the southeast quarter of section 36 it crosses Hickory Creek and follows along the south side of that stream's valley to the southwest corner of section 35 (17 N., 15 W.). At this point the horizon of the phosphate rock is exposed along both sides of the stream that enters Buffalo Fork in section 34; this outcrop crosses the head of this stream about three miles above its mouth in section 12 (16 N., 15 W.). From the mouth of this stream to the mouth of Spring Creek in section 21 (16 N., 15 W.) the St. Joe marble rests upon the lower Silurian rocks except where the phosphate rocks or their representatives intervene. The outcrop is very crooked, winding in and out, up one side of a ravine and down the other.

From the Mouth of Spring Creek to Calf Creek.—Less than a quarter of a mile northeast of the mouth of Spring Creek the Boone chert rests upon the St. Clair marble bed, and the phosphate horizon is between the two. The St. Clair marble is found along the south side of Buffalo Fork from this point to where it crosses to the north side of that stream about two miles below the mouth of Calf Creek, and thence along the north side of Buffalo Fork to the mouth of Mud Spring Branch, in the southwest corner of section 15, 16

North, 16 West. More in detail, it begins in 16 North, 15 West, section 21, the northwest quarter, follows the brow of the ridge southwest and crosses the east side of the section a quarter of a mile south of its northeast quarter; turning northeast it crosses the head of an affluent of Spring Creek an eighth of a mile west of the northeast corner of section 22, and then turns south and crosses the east side of this section about the middle, and then follows the general course of the stream to the northeast quarter of section 26 (16 N., 15 W.). From this last quarter section a tongue of land extends in a northwest direction forming the water-shed between the two main branches of Spring Creek; this tongue ends close to the middle of section 22. The phosphate horizon extends around the shoulder of this ridge following down the south side of the north branch, and up the north side of the south branch. It crosses the head of the main branch of Spring Creek a quarter of a mile west of where the road forks at the head of Hickory Hollow, in section 35, 16 North, 15 West. From this point westward its course along the south side of Spring Creek is very tortuous; three streams enter Spring Creek from the south, and the phosphate horizon follows up one side of each of these streams and down the other for a distance of more than a mile in each case. It crosses the line between sections 20 and 21 a little south of its middle and thence runs nearly due south, following the east side of the valley of Bald Knob Branch till it crosses the bed of that stream a little south of the middle of section 32, 16 North, 15 West. Thence it follows northward along the west side of that stream until it comes within a quarter of a mile of Buffalo Fork in the northwest quarter of section 20. It then turns to the south, and after crossing a small stream in a hollow a mile south of Buffalo Fork, turns due north again till it comes within a quarter of a mile of this stream, when it takes a northwest course, and for about a mile and a quarter keeps parallel with Buffalo Fork, and about an eighth of a mile away from it till the middle of the west side of section 18 is reached, when it makes a sharp turn and doubles back upon itself for more than a mile. A narrow neck of land is here capped by Boone chert, and beneath the chert is the St. Joe marble—the only point at which this bed overlies the phosphate horizon between the mouth of Spring Creek and the mouth of Calf Creek. From this neck the phosphate horizon runs southeast, then swings southwest, and finally westward till it crosses the west side of section 19 a third of a mile south of Buffalo Fork, and approaches within an eighth of a mile of Little Rocky Creek in section 24, 16 North, 16 West. Here the parting follows up Little Rocky Creek and after crossing its tributaries in the

heads of their hollows, crosses this stream near the middle of the north side of section 36 of the same township and range. It then turns north again and following along the left side of the valley of Little Rocky Branch at a distance of half a mile from Buffalo Fork, crosses the west line of section 24. Here it swings over to the drainage of Rock Creek, and turning southward follows up this stream at a distance of a quarter of a mile from it until it crosses its two branches in the northeast corner and in the southeast corner of section 1, of 15 North, 16 West; it then follows north again along the left side of this stream until in the northwest quarter of section 23, 16 North 16 West, it comes within an eighth of a mile of Buffalo Fork. This same horizon runs westward for a quarter of a mile and then turning sharply upon itself comes out over Buffalo Fork in a bluff just north of the middle of the west side of section 23. From this bluff it bears a little east, then south, and after following up several small hollows that head in sections 26 and 27, crosses the west line of section 27 at its middle, and then swinging west and south enters the drainage of Brush Creek. Up this stream it can be traced for about five miles to where it crosses this stream at the confluence of its two main forks in the southeast quarter of section 10, 15 North, 16 West. From this point it follows the left side of the valley of Brush Creek, winding in and out along its tributary hollows until it comes within a quarter of a mile of Buffalo Fork at the northwest corner of section 33, 16 North, 16 West. The total length of the outcrop of the phosphate horizen along both sides of Brush Creek is about eleven miles. From the northwest corner of section 33 this outcrop ascends the east side of the valley of Bear Creek for about three miles and crosses this stream in the northwest quarter of section 8, 15 North, 16 West; here it turns north and follows the west side of this stream for about two and a half miles until it approaches within a quarter of a mile of Buffalo Fork in the northwest quarter of section 31, 16 North, 16 West. From this last mentioned point the phosphate horizon ascends the south side of Buffalo Fork itself, and after several detours around the heads of short hollows, finally crosses that stream just below the ford in the southwest quarter of section 36, 16 North, 17 West.

The North Side of Buffalo Fork From Calf Creek to Water Creek.—North of Buffalo Fork the phosphate horizon keeps nearly parallel with that stream from where it crosses to the end of the bluff near the mouth of Dry Creek in section 31, 16 North, 16 West. From this point the outcrop ascends Dry Creek on its southwest side till it crosses this creek in the northeast quarter of section 25, 16 North, 17

West, and thence it descends along the northeast side of the stream to the fork of the roads in the northeast quarter of section 31, 16 North, 16 West. In section 30, of this township and range, on the southwest side of the creek the rocks occur in the following order, beginning at the top of the section:

1. Greenish yellow shale, with black phosphate pebbles in the bottom.
2. Lead-gray shale, with black phosphate nodules.
3. Sandy shale containing iron pyrites.
4. St. Clair marble.

The first three members of this section probably all belong with the Eureka shale. We have no record of the thickness of these beds at this place. A little further up the creek another section does not show the phosphate pebbles in the shale, but the overlying sandstone rests directly upon the St. Clair marble.

On the east line of section 31 the phosphate horizon comes down almost to Buffalo Fork and then strikes northeast, following the general trend of the river, but swinging away from it here and there to ascend the hollows draining into it, until it comes to an abrupt end at a fault in the southwest corner of section 15, 16 North, 16 West, at the side of Buffalo Fork, nearly half a mile north of the mouth of Tomahawk Creek. It is to be noted that at this point the St. Clair marble comes to an end; on the north side of the fault the phosphate horizon can be readily located by the St. Joe marble bed beneath which it lies.

Some apparently isolated deposits along the lower drainage of Tomahawk Creek should be mentioned at this place.

Near the middle of section 18, 16 North, 16 West, in the field opposite Leonard Keeling's house, fragments of a rich phosphate rock are scattered through the soil overlying the St. Clair marble. It is reported that this bed has been dug through and that it is four or five feet thiek. The same bed is exposed at the side of the field in the bank of Tomahawk Creek. The rock is a promising looking one and if it has sufficient areal distribution the deposit will prove to be a valuable one, for, as shown by the analysis, it contains over seventy-five per cent of calcium phosphate. The analysis is here given:

Analysis of phosphate rock from Keeling's place, 16 *North,* 16 *West, section* 18.

L. R. Lenox, Analyst.

Phosphoric acid (P_2O_5)	35.11	per cent.
Equivalent to calcium phosphate ($Ca_3P_2O_8$)	76.62	"
Oxides of iron and alumina	7.21	"

Beginning again on Mud Spring Branch at the fault nearly half a mile above where this stream enters Tomahawk Creek the phosphate horizon may be followed up stream to about the center of section 10, 16 North, 16 West, where it crosses the stream and descends its east side to the big bend of Buffalo Fork in the southwest quarter of section 15. Here it stands out in the bluff of the river, and from this bluff strikes due east for about two miles till it almost touches the east line of section 14. At this place it turns northward, and after various bends east and west reaches the southwest corner of section 1, 16 North, 16 West. Here it turns south again till it approaches within less than a quarter of a mile of Buffalo Fork, where it swings east and south and follows the general course of that stream to the brow of the hill southwest of Still House Hollow, near the middle of section 17, 16 North, 15 West. Turning northwest it here ascends Still House Hollow to the northwest corner of section 17, descends along the northeast side of that stream for half a mile and then turns northward and follows the bend of Buffalo Fork to the center of section 9, 16 North, 15 West.

The Water Creek Outcrop.—The outcrop of the horizon at which the phosphate rock is to be expected on Water Creek and its tributaries is very large; it probably amounts to as much as eighty miles in total length. One of the reasons for this great extent of outcrop is that a fault cuts across the upper ends of four of the tributaries of Water Creek, and as the upthrow is on the northwest side of the fault, erosion has cut down the uplifted side exposing many miles of outcrop that would not have been exposed had the horizontal beds remained undisturbed. The location of the phosphate horizon will be briefly given beginning near the mouth of Water Creek and following up the south side of that stream's valley.

Beginning at the center of section 9, 16 North, 15 West, the horizon follows up the southwest side of Water Creek to where the Yellville-Marshall road crosses it in the west half of section 35, 17 North, 16 West, where it crosses to the north side of the stream. Half a mile up stream a fault brings the outcrop to the surface again on the south side. From this point up stream it follows a zig-zag course, running up on side of the affluent and down the other, till it crosses the south branch of Water Creek at the road in the southwest quarter of section 30, 17 North, 16 West. At this place is the fault above mentioned, and an eighth of a mile farther up stream the outcrop appears again, and may be traced along the south side of the stream to the middle of the south side of section 23, 17 North, 17 West,

where it crosses to the north side and turns down stream to the break of the fault just mentioned. Southeast of the fault it follows close to Water Creek to the mouth of Taylor Fork, up which it turns again till it reaches the great fault in the southeast quarter of section 19, 17 North, 16 West. Passing to the north side of the fault the outcrop swings suddenly half a mile away from the stream and crosses the drainage on the west line of section 24, 17 North, 17 West. From this point this outcrop does not follow far down the stream, but in its general bearing it strikes northeast, winding back and forth on the southeast side of the water-sheds to a point half a mile southeast of Cedar Glade post-office, and near the southeast corner of section 4, 17 North, 16 West. The strike of the outcrop runs south from this section corner about a mile, when it ends abruptly against the fault. Returning to the fault on Taylor Fork the outcrop follows the north and east side of this stream to its mouth and down Water Creek to the mouth of Barren Fork, up Barren Fork to where it crosses the road in section 20, 17 North, 16 West, down this stream on the north side to the northwest quarter of section 27, where it turns up an affluent entering here from the north, and up this to the northeast corner of section 16, 17 North, 16 West. Here it turns south along the east side of this stream to the mouth of Barren Fork, when it returns northward, following up the west side of another stream which it crosses in the southeast quarter of section 10, 17 North, 16 West, then following nearly due south on its east side to near where this stream enters White Oak Branch and crosses this stream in the south half of section 14, 17 North 16 West, descends along its east side to the mouth of White Oak Branch, it turns northward up White Oak Branch and to the fault crossing Water Creek just below. Southeast of the fault in section 35 the outcrop on the northeast side of Water Creek follows to the mouth of Caney Creek, up this stream to the northeast quarter of section 24, down the east side of it and of its affluents to Water Creek again, and then down this stream to Bear Pen Branch, up the latter on the west side, and down it on its east side, till it approaches Buffalo Fork in the southwest corner of section 4, 16 North, 15 West.

From Water Creek to Clabber Creek.—We shall not attempt to follow the details of the outcrop of the phosphate horizon between Water Creek and Clabber Creek. Between the streams entering Buffalo Fork from the west, the outcrop comes down to within a quarter of a mile of Buffalo Fork, while it follows up each of these tributaries from one to four miles. These streams are Saltpeter Hollow, Jim Hollow, Panther Creek, and Little Panther Creek.

On Rush Creek (17 North, 15 West,) there is a fault along which that stream flows. North of this fault the contact between the Carboniferous and Ordovician rocks is in the hilltop; and if there is any phosphate bed in this contact zone, it is so thin that it was overlooked in the several sections we made across it. On the south side of the valley—the down-throw side of the fault—a bed of sandstone, probably the Sylamore sandstone, is enclosed between two marble beds. When this rock was examined phosphate nodules were not looked for, and it cannot be positively stated whether or not there are any considerable beds in this vicinity. West of Rush post-office the outcrop follows the course of Rush Creek to the mouth of Barney Hollow, which it ascends to the northwest quarter of section 18, 17 North, 15 West; and descending along its west side to near its mouth is ascends to the South Fork of Cold Water Branch, then it follows the latter stream itself to near Cedar Glade post-office, where it crosses the stream and returns eastward on the north side near where it enters Rush Creek.

The limits imposed upon the present preliminary report do not permit further detail regarding the location of the phosphate bearing horizon in this portion of northern Arkansas. It may be said in general terms, however, that this horizon swings across the highlands about the head waters of Mill Creek, from three to five miles south and southwest of Yellville; it encircles a high water-shed three miles southwest of Yellville; it outcrops around the upper part of Greasy Creek; it follows down the water-shed between Greasy Creek and Hampton Creek to within an eighth of a mile of Crooked Creek; it lies along Hampton Creek on both sides and has over twenty miles of outcrop in the vicinity of Bruno; it follows up all the tributaries of Clear Creek to a point three miles south of Glencoe; it has some thirty miles of outcrop on Tomahawk Creek above Tomahawk post-office.

The Beds Near St. Joe, Searcy County.—At St. Joe, the contact between the Carboniferous and Silurian rocks is exposed about three-quarters of a mile above the village, in the bluff where South Mill Creek enters Monkey Run.

The section at this place is as follows:

Chert and cherty limestone (Boone chert)	35	feet
Light colored marble	10	"
Pink marble (St. Joe bed)	40	"
Sandy conglomerate	4	inches
Olive green shale with phosphate nodules	2	feet
Sandy conglomerate with black phosphate nodules	3	"
Concealed	4	"
St. Clair pinkish marble	5	"

This last marble bed is 25 feet thick in all and below is the blue Izard limestone. Analysis of the black phosphate nodules from this section showed them to have the following composition:

Analysis of phosphate nodules from Monkey Run, near St. Joe.

L. R. Lenox, Analyst.

	Per cent.
Phosphoric acid, (P_2O_5)	31.75
Equivalent to calcium phosphate ($Ca_3P_2O_8$)	69.31
Oxides of iron and alumina	8.10

Just north of this exposure the St. Joe fault carries this line of contact to near the hilltop, over 200 feet higher. In this hilltop the contact beds were not observed.

On the southwest side of Monkey Run, where the St. Joe and Harrison road turns to the right and ascends the hill, the parting is indicated by a bluish olive-green bed, about three feet thick, containing phosphate nodules. Analysis was made of the brown phosphate nodules from this bed with the following results:

Analysis of phosphate nodules from Monkey Run, near St. Joe.

L. R. Lenox, Analyst.

	Per cent.
Phosphoric acid, (P_2O_5)	25.92
Equivalent to calcium phosphate ($Ca_3P_2O_8$)	56.58
Oxides of iron and alumina	9.01

This bed is mentioned by Owen in his first report; but he did not suspect its true nature, for he speaks of it as a "vein of ore containing iron and manganese."*

Upper Buffalo.—About three miles southwest of the village of St. Joe, on the head waters of Johnson's Creek, the phosphate horizon is exposed in sections 23, 24, 25 and 26 of 16 North, 18 West. We have no notes on the phosphate rocks of this region, but the general geology of the region suggests the advisability of a careful examination of the interval between the St. Joe marble and the St. Clair marble. There is another isolated area at Burnt Mill and south and southeast of that place in sections 27 and 34.

On Upper Buffalo the uplift side of the northeast-southwest fault that passes near St. Joe brings out an enormous length of outcrop of the phosphate horizon. It begins on Buffalo just above the mouth of Richland Creek, ascends Cave Creek to a mile above Cave Creek postoffice, ascends Big Creek to the foot of Big Creek Mountain, ascends

*First Report of a Geological Reconnoissance of the Northern Counties of Arkansas, by D. D. Owen, Little Rock, 1858, p. 79.

Little Buffalo to the mouth of Henson Creek and Henson Creek some five miles, ascends Big Buffalo to a point several miles south of Boxley; it crops out in Cecil's Cove, in Gaither Cove; it ascends Mill Creek to Marble City, and Wells Creek to the base of Pinnacle Mountain, ascends Davis Creek to the base of Boat Mountain, to say nothing of the hundreds of minor streams and hollows that drain into these larger ones. We add a couple of notes made on the character of the rock observed along the phosphate horizon.

The Sylamore sandstone on Cave Creek is exposed at the mouth of "Saltpeter Cave," in 15 North, 19 West, section 27. We have not visited this locality; and the notes on this district were made by Prof. T. C. Hopkins, while working up the marble beds of the region.

The space between the St. Joe above and the St. Clair marble below is occupied by a bed of shale from 12 to 14 inches thick. At the bottom of this shale is siliceous, black and lumpy layer of nodules; similar nodules are scattered through the St. Joe marble for a foot or more from the bottom.

On the north side of Little Buffalo, in 16 North, 21 West, section 26, 200 yards above the third ford below Jasper, is an exposure of shale that contains pebbles resembling the Sylamore sandstone.

In 16 North, 21 West, section 9, on the north side of Big Buffalo, and 200 yards above the mouth of Sneed's Creek, the Sylamore sandstone is from two to six inches thick and contains black pebbles.

Upper Crooked Creek.—Above the mouth of Clear Creek near Powell, the phosphate horizon follows up the south side of Crooked Creek, swinging well to the south around the head waters of its tributaries entering that stream from the south, and following Pedlo Creek and Huzza Creek as far south as Bellefonte. It crosses Crooked Creek about a mile below Harrison, Boone County, and follows up the tributaries entering that stream from the north: Short Creek, Silver Creek, Sand Lick Creek, White Oak Creek, etc., and follows around the long ridge that separates Crooked Creek from Sugar Orchard Creek, making a sharp point half a mile west of the mouth of Sugar Orchard. Up Sugar Orchard the horizon reaches to near the middle of section 10, 19 North, 19 West; up Mill Hollow it passes E. J. Rhodes' place in section 9, 19 North, 18 West; it goes up Tar Kiln Creek, and little Sugar Orchard and runs round the head waters of George's Creek.

North and West of Flippin.—West of Flippin the phosphate horizon runs round the head waters of Moccasin Fork, Jimmy's Creek,

Sister Creek, Music Creek, Coon Creek, Lead Mine Hollow, Chapman's Branch and Pigeon Roost Branch. From near Dodd City the general trend of the horizon is nearly due west in the direction of Elixir Springs, but in detail the course is very irregular. It caps the hills about the head waters of Upper Sugar Loaf Creek, Malden Creek, Cheatham Creek, Bear Creek and Prairie Creek. It also extends around the head of Bee Creek, Cricket Creek, and ascends Long Creek as far as section 35, 21 North, 22 West, and Yocum Creek to section 20, 21 North, 22 West.

Carroll County and Westward.—The phosphate horizon west of the Yocum Creek exposures outcrops east of Indian Creek in 21 North, 24 West, section 12, and its course is thence almost due south to the southwest corner of section 31, 20 North, 23 West, about two miles and a half west of Green Forest. From this point it strikes northwest, encircling the hills between there and Berryville, and then turning and following a southeast course up the valley of Osage Creek to 18 North, 23 West, section 15. Here it crosses to the left side of Osage Creek and follows down it to the north point of Crystal Mountain, swings south around the head of Lundy's Cove and around Farmer's Cove, around the north point of Pension Mountain and Trigger Mountain, where it is near King's River. It ascends King's River to Piney Creek, ascends this to section 14 in 18 North, 24 West, ascends Dry Fork to a point a mile above Omega post-office, crosses to the west side of King's River in section 32, 18 North, 25 West, ascends Pine Creek three miles, ascends several tributaries of King's River from the west to Rock House Creek, and goes up that stream to section 11, 18 North, 26 West, and then further north it ascends William's Hollow, Keel's Creek, Greenwood Hollow and Cedar Creek. From the mouth of this last stream it strikes northward, and with many bends reaches Boat Mountain, in 21 North, 25 West, sections 19 and 20. West of this point this horizon ascends White River and almost all its tributaries (Leatherwood, North Clifty, Big Clifty, Little Clifty, Spider, Indian, Ford, Pulham Branch, Ventry Branch, Prairie) as far south as section 24, 18 North, 29 West. There are besides some isolated exposures on War Eagle Creek: one northeast of Huntsville, about the mouths of Huston and Bohannon Creeks; another south of War Eagle Mills, besides several smaller ones. In Benton County this horizon is exposed along Little Sugar Creek from section 12, 20 North, 31 West, to the Missouri line; about Sulphur Springs it extends up Seiler's Branch, Horse Creek and Butter Creek. It is exposed at several places along Illinois River (Ladd's Mill and Rickert post-office) and Osage Creek.

In Madison County, 16 North, 26 West, a quarter of a mile south of the southeast corner of section 1, the junior author found a bed of limestone conglomerate, the materials of which strongly resembles phosphate nodules. It was analyzed and found to contain only about 8 per cent of calcium phosphate. This rock is a very promising one in appearance and we would urge the importance of a further examination of the locality and of the horizon at which this conglomerate was found.

Our notes upon the zinc deposits contain many references to the phosphate bed at the contact between the Boone chert or St. Joe marble and the Ordovician rocks. This bed is exposed in many of the shafts, drifts and prospect pits through Marion and Boone Counties, for the zinc is frequently found just below the St. Joe marble. It is hardly necessary, however, to do more than state this general fact, for it is impossible to mention all the pits and sections in which the phosphate bed or its representative is found. In any general search for the distribution of the phosphate horizon through the northern part of the state, use can be made of the atlas accompanying the Zinc report of the Geological Survey of Arkansas, and of the maps of Benton and Washington Counties. Where there is zinc ore the phosphate horizon is, for the most part, just above the zinc-bearing rocks.

THE CRETACEOUS PHOSPHATE REGION.

The second region in which phosphate rocks occur in the State of Arkansas has been indicated as the Cretaceous area of the southwestern part of the State. But little is known of the exact extent, thickness or richness of the phosphate beds in this part of the state, and what is here said must be regarded only as suggestions, but, it is hoped, worthy of attention.

The distribution of the Cretaceous rocks is shown in a general way on the map accompanying the Geological Survey's report on the Mesozoic rocks of the state. The upper limit, however, of the Cretaceous beds is better shown on the map of the Tertiary Report. These rocks are made up of marls, chalks, sandstones and clays. In some of the beds there are bands of black pebbles which were formerly regarded as chert or quartz; a chemical examination of these pebbles, however, show that many of them are phosphate nodules. Such bands may be seen in the rocks exposed on Desciper Creek, west of Akadelphia, in Clark County. We have never seen these pebbles

sufficiently abundant to make the deposits valuable, but an examination of the Cretaceous rocks with these facts in view may lead to the discovery of such deposits.

Another possible source of phosphates in the Cretaceous area of southwest Arkansas is to be found in the green sand marls. Some of these marls are very like those of New Jersey, and are, in all probability, available for the same purposes as those for which they have long been so extensively and successfully used in New Jersey, namely, for direct application as fertilizers to the soil. No thorough practical test, however, has ever been made of the Arkansas greensands.

In France similar greensands are now used for the manufacture of high grade fertilizers, and it is suggested that possibly the Arkansas beds may be handled in the same way. At Bellegarde sur-Valserine, Ain, France, the greensand beds are exposed in horizontal beds from four to six feet thick on the banks of the River Rhone. The beds are mined by drifts; the crude material is run through a crusher, and thence passed through water into ordinary revolving wire screens, which allow the fine sands and worthless matter to be washed out, while the phosphate nodules which are hard enough to resist crushing in the rollers fall out at the ends and are afterwards used as rock phosphates for the manufacture of high-grade fertilizers.

We have noted the greensand beds at Washington, Hemstead County, where they are exposed between the railway station and the Garland place. In any examination of the Cretaceous area of the State it should be kept in mind that the rocks are all of marine origin and that they all have a gentle southeast dip, so that any one bed lies at a constantly lower level as it is followed toward the south and east.

THE OUACHITA PHOSPHATE REGION.

The study of the Silurian rocks of the State never having been completed by the Geological Survey, it has not been possible to correlate the beds north of the Boston Mountains with those of the Silurian area of the Ouachita uplift or great anticline belt that crosses the State from south of Little Rock to Dallas, Polk County.

In the Ouachita region the Lower Coal Measures or Pennsylvanian rocks rest upon Silurian rocks, so that there is, so far as we are now aware, no representative of either the Upper Silurian, De-

vonian, or Lower Carboniferous rocks. It will be remembered that the phosphate beds of North Arkansas occupy the position of the Devonian rocks, that is, they are below the Lower Carboniferous beds (the Boone chert) and above the Lower Silurian beds. If the theory suggested for the origin of these phosphate beds is correct, we should expect beds of a similar character to occupy the still larger gap between the Lower Silurian and the Lower Coal Measures in the Ouachita region.

Conglomerate beds are known in the Ouachita uplift, which bear so striking a resemblance to the Sylamore sandstone that they are scarcely to be distinguished in hand-specimens. The only apparent difference is that the Ouachita uplift specimens appear to be a little more crystalline or metamorphosed. On account of the crushing of the rocks throughout this southern area this was to be expected. Owing to the folded, faulted and metamorphosed condition of the rocks in this region, and to the almost total absence of fossils, it cannot be positively stated whether or not these conglomerates are the equivalents of the Sylamore sandstone of North Arkansas.

We have seen specimens of this conglomerate from several places north and south of the city of Hot Springs, but an analysis of one of these specimens did not show it to be rich enough in phosphoric acid to have any value. It is possible that these rocks are worthless, but the question is worth investigation. Such a conglomerate occurs in 1 South, 19 West, section 6, southeast quarter, on the Hot Springs-Fort Smith road. These rocks have a northward dip of 75 degrees and a thickness of about 200 feet. A similar conglomerate is reported from 1 North, 20 West, section 35, northwest quarter.

As the rocks throughout the region of the Ouachita uplift are much folded, the distribution of a phosphate bed will not be so easily traced as in the region of horizontal beds in the Boston Mountains region.

It may be of some service in future examinations of this Ouachita region for phosphates to remember that the novaculites seem to be confined to the Silurian rocks and that the Upper Silurian-Devonian interval in which it seems probable that the phosphates may be found, is at the top of the novaculite series.

In the region of the Lower Coal Measure rocks in the vicinity of Amity, Clark County, a conglomerate found by Dr. George H. Ashley, resembles the phosphate rock somewhat; but a chemical examination of one sample of it showed it to contain only about 9 per cent of calcium phosphate. Further search in the neighborhood of Amity may lead to the discovery of richer deposits.

ANALYSES OF ARKANSAS PHOSPHATES.

For purposes of comparison we have brought together here most of the analyses we have had made of the Arkansas phosphate rocks. These analyses are not of car-load lots, but neither do they represent picked samples, but simply fair average specimens, such as the geologist is accustomed to gather for purposes of study. It will be observed that analyses have been made only of materials from the northern part of the State.

Analyses of the better grades of Arkansas phosphate-rocks.

LOCALITY.	Phosphoric Acid, P_2O_5	Equivalent to Calcium Phosphate, $Ca_3P_2O_8$	Oxides of Iron and Alumina.
	Per cent.	Per cent.	Per cent.
§Milligan place, specimens from inside of cave.	26.13	57.03	5.89
	26.77	58.43	5.86
	29.40	64.17	3.08
	29.98	65.43	3.8[illegible]
§Milligan place, specimens from boulders on surface	31.06	67.79	8.01
	31.11	67.90	7.05
§Milligan place, specimens from small surface fragments	33.54	73.20	5.19
	33.86	73.90	5.09
†Milligan place, washed pebbles	....	73.76	3.82
†Milligan place, fragments	....	62.03	2.97
‡SW ¼ Sec. 8, 14 N., 7 W.	....	62.47	....
	....	67.40	....
*Meeker place, near Cushman	22.62	49.38	8.82
†SW ¼ Sec. 12, 14 N., 8 W., general sample	....	58.31	5.85
†NW ¼ Sec. 13, 14 N., 8 W., 30-inch bed	....	55.27	8.33
†West of the center of the NW ¼ of Sec. 13, 14 N., 8 W., 21-inch bed	....	51.49	7.57
†NW ¼ Sec. 13, 14 N., 8 W., 12-inch bed	....	54.93	8.96
†NE ¼ Sec. 14, 14 N., 8 W., 18-inch bed	....	68.72	8.31
†SW ¼ Sec. 14, 14 N., 8 W., in Pine Hollow, 16-inch bed	....	68.72	4.98
†Pine Hollow (calcined rock)	....	69.02	4.92
†SW ¼ Sec. 11, 14 N., 8 W., 6-inch bed	....	62.70	8.74
†SW ¼ Sec. 11, 14 N., 8 W., 8-inch bed	....	60.07	7.38
¶SW ¼ Sec. 11, 14 N., 8 W., surface fragments	....	56.81	8.97
†Near Center E ½ Sec. 15, 14 N., 8 W., 27-inch bed	....	70.40	7.03
†SE ¼ Sec. 4, 14 N., 8 W., 12-inch bed	....	58.27	5.79
†SE ¼ Sec. 4, 14 N., 8 W., 8-inch bed	....	55.57	6.18
†NE ¼ Sec. 4, 14 N., 8 W., 12-inch bed	....	66.39	4.13
†NE ¼ Sec. 4, 14 N., 8 W., 14-inch bed	....	62.05	7.18
†NW ¼ Sec. 5, 14 N., 8 W., 4-inch bed	....	59.68	6.73
*Monkey Run, black nodules	31.75	69.31	8.10
*Keeling's place, Searcy Co., buff nodules	35.11	76.62	7.21
*Southwest of Monkey Run, Searcy Co., brown nodules	25.92	56.58	9.01

§Maxwell Adams, analyst, Stanford University, Calif.
†Analyses by J. Ross Hanahan, Charleston, S. C.
‡Analyses by Ledoux Chemical Company, New York.
*By L. R. Lenox, Stanford University, Calif.
¶Analyses by Davis & Lyons, Bloomington, Ind.

General table of analyses of Arkansas phosphates.

No.	LOCALITY.	Phosphoric Acid, P_2O_5	Calcium Phosphate, $Ca_3P_2O_8$	Iron and Alumina, Fe_2O_3 and Al_2O_3
1	§Milligan place, specimens from inside	26.77	58.43	5.86
2	of cave	26.13	57.03	5.89
3	§Milligan place, second set of inside	29.40	64.17	3.08
4	samples	29.98	65.43	3.87
5	§Milligan place, specimens from boul-	31.06	67.79	8.01
6	ders on the surface	31.11	67.90	7.05
7	§Milligan place, specimens from small	33.54	73.20	5.19
8	surface fragments	33.86	73.90	5.09
9	†Milligan place, 60-inch bed	....	47.19	....
10	†Milligan place, washed pebbles	....	73.76	3.82
11	†Milligan place, surface fragments	....	62.03	2.97
12	¶St. Clair Spring, phosphatic limestone	....	48.27	5.61
13	¶Mouth of Cave Creek	....	43.61	23.00
14	¶NE ¼ Sec. 30, 14 N., 6 W., black pebbles	....	72.54	8.64
15	¶NE ¼ Sec. 30, 14 N., 6 W., yellow rock	....	49.62	20.33
16	¶SE ¼ Sec. 23, 14 N., 7 W., surface fragments	....	36.07	19.83
17	¶Mr. Miller's, in the S. ½ of Sec. 15, 14 N., 7 W., Sample from surface fragments	....	41.52	14.33
18	†Opposite Farrell's cave, average sample.	....	34.13	....
19	†Opposite Farrell's, average sample	....	44.79	....
20	†Opposite Farrell's, 9-inch bed	....	50.79	11.68
21	†Opposite Farrell's, 32-inch bed	....	48.53	....
22	†Opposite Farrell's, 12-inch bed	....	44.45	....
23	†Opposite Farrell's, surface fragments	....	46.72	....
24	¶Opposite Farrell's, surface fragments	....	52.51	17.02
25	‡Opposite Farrell's cave	....	62.47	....
26	‡Opposite Farrell's cave	....	67.40	....
27	†Opposite Farrell's, unweathered sandstone	....	6.48	....
28	Meeker Place, near Cushman, average sample	22.62	49.38	8.82
29	¶Meeker Place, unweathered fragment	....	27.46	13.15
30	¶Hightower's, west of Cushman	....	38.60	15.80
31	†SW ¼ Sec. 12, 14 N., 8 W., average sample	....	58.31	5.85
32	¶SW ¼ Sec. 12, 14 N., 8 W., surface fragments	....	33.21	14.21
33	†SW ¼ Sec. 12, 14 N., 8 W., upper bed	....	33.57	....
34	†SW ¼ Sec. 12, 14 N., 8 W., lower bed	....	55.98	....
35	†NW ¼ Sec. 13, 14 N., 8 W., 13-inch bed (Fig. 6)	....	39.65	....
36	†NW ¼ Sec. 13, 14 N., 8 W., 9-inch bed (Fig. 6)	....	41.27	....

§Maxwell Adams, analyst, Stanford University, Calif.
†Analyses by J. Ross Hanahan, Charleston, S. C.
¶Analyses by Davis & Lyons, Bloomington, Ind.
‡Analyses by Ledoux Chemical Company, New York.

General table of analyses of Arkansas phosphates.

No.	LOCALITY.	Phosphoric Acid, P_2O_5	Calcium Phosphate, $Ca_3P_2O_8$	Iron and Alumina Fe_2O_3 and Al_2O_3
37	†NW ¼ Sec. 13, 14 N., 8 W., 30-inch bed (Fig. 6)	....	55.27	8.33
38	†NW ¼ Sec. 13, 14 N., 8 W., 6-inch bed (Fig. 6)	....	50.67	8.52
39	†NW ¼ Sec. 13, 14 N., 8 W., 10-inch bed (Fig. 6)	....	50.66	9.97
40	†NW ¼ Sec. 13, 14 N., 8 W., 24-inch bed (Fig. 7)	....	57.98	10.52
41	†NW ¼ Sec. 13, 14 N., 8 W., 12-inch bed (Fig. 7)	....	15.47	....
42	†NW ¼ Sec. 13, 14 N., 8 W., 30-inch bed (Fig. 7)	....	36.54	....
43	†NW ¼ Sec. 13, 14 N., 8 W., 10-inch bed (Fig. 7)	....	29.43	....
44	†NW ¼ Sec. 13, 14 N., 8 W., 21-inch bed (Fig. 8)	....	51.49	7.57
45	†NW ¼ Sec. 13, 14 N., 8 W., 12-inch bed (Fig. 9)	....	54.93	8.96
46	†NE ¼ Sec. 14, 14 N., 8 W., 18-inch bed (Fig. 10)	....	68.72	8.31
47	†NE ¼ Sec. 14, 14 N., 8 W., 18-inch bed (Fig. 10), after crushing and washing	....	68.45	....
48	†NE ¼ Sec. 14, 14 N., 8 W., 10-inch bed (Fig. 11)	....	57.39	9.80
49	†NE ¼ Sec. 14, 14 N., 8 W., 18-inch bed (Fig. 11)	....	48.42	....
50	†NE ¼ Sec. 14, 14 N., 8 W., 10-inch bed (Fig. 11)	....	15.76	15.66
51	†NE ¼ Sec. 14, 14 N., 8 W., 14-inch bed (Fig. 11)	....	44.25	....
52	†NE ¼ Sec. 14. 14 N., 8 W., Pine Hollow	....	68.22	4.98
53	†NE ¼ Sec. 14. 14 N., 8 W., Pine Hollow (calcined)	....	69.02	4.92
54	¶NE ¼ Sec. 14, 14 N., 8 W., Pine Hollow surface fragments	....	51.65	6.03
55	¶SW ¼ Sec. 11, 14 N., 8 W., surface fragments	....	56.81	8.97
56	†SW ¼ Sec. 11, 14 N., 8 W., 6-inch bed (Fig. 13)	....	62.70	8.74
57	†SW ¼ Sec. 11, 14 N., 8 W., 18-inch bed (Fig. 13)	....	60.07	7.38
58	†SW ¼ Sec. 11, 14 N., 8 W., 11-inch bed (Fig. 13)	....	47.19	....
59	†SE ¼ Sec. 10, 14 N., 8 W., 22-inch bed (Fig. 14)	....	41.85	....

†Analyses by J. Ross Hanahan, Charleston, S. C.
¶Analyses by Davis & Lyons, Bloomington, Ind.

General table of analyses of Arkansas phosphates.

No.	LOCALITY.	Phosphoric Acid, P_2O_5	Calcium Phosphate, $Ca_3P_2O_8$	Iron and Alumina, Fe_2O_3 and Al_2O_3
60	†SE ¼ Sec. 10, 14 N., 8 W., 22-inch bed, top layer (Fig. 14)	....	43.16	....
61	†SE ¼ Sec. 10, 14 N., 8 W., 22-inch bed, bottom layer (Fig. 14)	....	50.14	....
62	¶SE ¼ Sec. 10, 14 N., 8 W., surface fragments	....	44.54	21.48
63	†E ½ Sec. 15, 14 N., 8 W., 27-inch bed (Fig. 15)	....	70.40	7.03
64	¶E ½ Sec. 15, 14 N., 8 W., average sample	....	59.55	15.05
65	†SE ¼ Sec. 4, 14 N., 8 W., 12-inch bed (Fig. 16)	....	58.27	5.79
66	†SE ¼ Sec. 4, 14 N., 8 W., 8-inch bed (Fig. 16)	....	55.57	6.18
67	¶SE ¼ Sec. 4, 14 N., 8 W., surface fragments	....	63.72	13.80
68	†NE ¼ Sec. 14, 14 N., 8 W., 12-inch bed (Fig. 17)	....	66.39	4.13
69	¶NE ¼ Sec. 4, 14 N., 8 W., surface fragments	....	48.32	14.47
70	†S ½ Sec. 4, 14 N., 8 W., 14-inch bed (Fig. 18)	....	62.05	7.18
71	¶S ½ Sec. 4, 14 N., 8 W., surface fragments	....	55.19	11.23
72	¶NE ¼ Sec. 5, and SE ¼ Sec. 32, 15 N., 8 W., surface fragments	....	35.25	23.32
73	†SW ¼ Sec. 5, 14 N., 8 W., 9 and 10-inch beds (Fig. 19)	....	3.27	....
74	¶SW ¼ Sec. 5, 14 N., 8 W., surface fragments	....	67.53	7.71
75	†NW ¼ Sec. 5, 14 N., 8 W., 4-inch bed (Fig. 20)	....	59.68	6.73
76	†NW ¼ Sec. 5, 14 N., 8 W., sandstone (Fig. 20)	....	36.04	....
77	†NW ¼ Sec. 5, 14 N., 8 W., 18-inch bed (Fig. 21)	....	32.94	....
78	†NW ¼ Sec. 5, 14 N., 8 W., phosphate sandstone	....	10.23	....
79	†SE ¼ Sec. 6, 14 N., 8 W., phosphate sandstone (Fig. 22)	....	28.01	....
80	†SE ¼ Sec. 6, 14 N., 8 W., 10-inch bed	....	37.36	....
81	¶SE ¼ Sec. 6, 14 N., 8 W., surface fragments	....	48.27	8.61
82	†Center Sec. 6, 14 N., 8 W., 12-inch bed	....	26.16	....
83	*Monkey Run, black nodules	31.75	69.71	8.10
84	*Keeling's place, Searcy Co., buff nodules	35.11	76.62	7.21
85	*Southwest of Monkey Run, Searcy Co., brown nodules	25.92	56.58	9.01

†Analyses by J. Ross Hanahan, Charleston, S. C.

¶Analyses by Davis & Lyons, Bloomington, Ind.

*By L. R. Lenox, analyst, Stanford University, Calif.

Conclusions From the Analyses.—The preceding tables include all the analyses at our command. They are given regardless of whether the materials are available for the manufacture of high-grade fertilizers. It is evident at a glance that in the majority of cases given the iron and alumina contents are high for the manufacture of high-grade fertilizers.* We are far from believing, however, that these analyses condemn the phosphate rocks of North Arkánsas.

In the first place the whole area over which the phosphate beds occur or are to be expected, has not been examined, and it is not known, therefore, how much the materials vary in character and composition. Judging from what is already known, it seems reasonable to suppose that better deposits than any thus far found may yet be discovered.

In the second place Dr. Wyatt points out that "superphosphates of exceptionally good quality" may be made of phosphate rocks "containing as high as eight per cent of iron and alumina."†

The point, however, to which we would direct especial attention, is that *all of these rocks, even those running high in iron and alumina, may be used directly as fertilizers.*

This is a fact of the first importance to the owners of phosphate lands and to the farmers of the South. This method of fertilizing is now being successfully used in the southwestern part of France, where there are phosphate deposits similar to those of Arkansas.‡ The natural rock is there ground to a fine powder and spread upon bottom lands, from 450 to 600 pounds to the acre. On one estate near Osse the black phosphates were used where the results could be compared with those obtained from the use of super-phosphates and stable manure. The land was what we call "bottoms"; the raw phosphate rock was finely ground and 600 pounds used to the acre. The crops were Irish potatoes and corn. The planter reports that the results obtained from the raw ground phosphate rock were quite as good as those had from the use of stable manure and from the high-priced super-phosphates.

*"This *tolerated amount*, however, must not exceed three per cent by weight of the mass, and every additional per cent of oxides of iron and alumina is to be compensated for by a proportionate deduction from the total quantity of phosphate of lime." The Phosphates of America. By Francis Wyatt, page 139. New York, 1894.

†The Phosphates of America, by Francis Wyatt, p. 114.

‡The French deposits, methods of using the rock and the results of recent experiments are described in an article entitled: Mémoire sur les phosphates noirs des Pyrenées. Par David Lavat, Annales des Mines, 9me. sér. vol. XV., pages 5 to 100. Paris, 1899.

There is nothing new, however, in these results. Dr. Wyatt in his valuable work upon the phosphates of America, writes as follows in regard to a phosphate as high as *thirty-one per cent in iron and alumina*:* "It appears to have been forgotten, overlooked, or ig-"nored, by the opponents of these phosphates that the phosphoric "acid in the soil invariably exists in the form of phosphates of iron "and alumina. The so-called experts had probably not then learned "what they are now compelled to admit, that although some difficulty "may attend their decomposition in the factory or their transforma-"tion into chemical fertilizers, *these phosphates are extremely val-"uable in the raw state—if very finely ground—as a direct manure.*"

The italics are ours. Another fact which should not be overlooked in this connection is that the constitution and physical condition of the soil should not be neglected. The grinding of the rock also costs something; this cost is estimated to range from fifty cents to two dollars per ton.

TRANSPORTATION AND MARKET.†

Transportation.—One of the greatest difficulties at present in the way of any development of the phosphate deposits of the State is the absence of prompt and cheap transportation facilities. It is true that the White River flows through the phosphate region; but that stream furnishes an uncertain and unsteady means of shipment. Moreover, freight would have to be transferred to the railway either at Batesville or at Newport, or it would have to make the long, tedious voyage down to the mouth of White River, and thence up the Mississippi to Memphis or St. Louis, or down to New Orleans.

The deposits now known nearest to the railways are those in the vicinity of Cushman; and it is for these convenient deposits only that favorable rates are now available.

If the disadvantages of transfer from boat to railway and high railway rates were removed, there would still be a considerable and, at present, uncertain cost of hauling from the remote mines to the boats, always over bad country roads. If these deposits are ever to be utilized the common roads must be made passable at all seasons of the year, the railways must find it possible to offer rates that will leave the shipper a margin of profit, and the phosphate lands them-

*The Phosphates of America, by Francis Wyatt, 5th ed., p. 21. New York, 1894.

†Since this report was written two railroads have begun building through the region.—R. L. Bennett, Director.

selves must come into the hands of the operators at rates that will not require them to pay interest on an enormous capital invested in lands. With the competition of the deposits of South Carolina, Florida and Tennessee, the Arkansas product must be mined and removed cheaply if it is to be mined at all. If the phosphate lands of the State are bought up by speculators and sold at high prices, the business of mining and shipping this mineral in the State of Arkansas will die before it is born. Only extraordinarily rich deposits could be worked profitably under such conditions.

Market.—St. Louis seems to be well adapted to the manufacture of fertilizers, both on account of railway facilities, its location with reference to the users of fertilizers, and also on account of the cheapness and convenience of sulphuric acid at that place. In any contemplated manufacture of fertilizers in the State of Arkansas one must consider the necessarily high freight rates that will have to be paid on the sulphuric acid required, and the advantages and disadvantages of the site of a factory as a distributing point for the manufactured article.

BRIEF LIST OF PUBLICATIONS UPON ROCK PHOSPHATES.

1. The American Fertilizer. An illustrated magazine, published at Philadelphia.

2. Mineral Phosphates as Fertilizers. By *H. W. Wiley.* Yearbook of the United States Department of Agriculture for 1894, pp. 177-192.

3. Nature and Origin of Deposits of Phosphate of Lime. By *R. A. F. Penrose, Jr.* Bulletin 46 of the United States Geological Survey. Washington, 1888. (This work contains a full bibliography of the subject up to the date of its publication.

4. The Phosphates of America. By *Francis Wyatt.* Fifth edition, New York, 1894.

5. Florida, South Carolina and Canadian Phosphates. By *C. C. Hoyer Millar.* London, 1892.

6. The Non-Metallic Minerals. By G. P. Merrill. Rep. United States National Museum for 1899, pp. 356-382. Washington, 1901.

7. Étude sur l'Industrie des Phosphates et Superphosphates, Par *David Lavat.* Annales des Mines 9me serie. Vol. VII., pp. 5-260. Paris, 1895.

8. Mémoire sur les phosphates noirs des Pyrénées. Par *David Lavat.* Annales des Mines, 9me serie. Vol. XV. pp. 5-100. Paris, 1899.

9. The Phosphates of Tennessee. By *T. C. Meadows* and *L. Brown*. Transactions American Institute of Mining Engineers, XXIV., 582-594. New York, 1894.

10. The White Phosphates of Tennessee. By *C. W. Hayes*. Transactions American Institute of Mining Engineers, XXV., 19-28 New York, 1895.

11. The Tennessee Phosphates. By *C. W. Hayes*. Seventeenth Ann. Rep. United States Geological Survey, part II., pp. 513-550. Washington, 1896.

12. New Source of Phosphate Rock in Tennessee. By *J. M. Safford*, American Geologist, October, 1896, Vol. XVIII., p. 261-264.

13. The Americant Phosphate Company's Plant near Mount Pleasant, Tennessee. By *G. F. Blackie*. Engineering and Mining Journal, July 7, 1900, pp. 7-8.

14. The Phosphate Deposits of Arkansas. By *John C. Branner*. Transactions American Institute of Mining Engineers, Vol. XXVI., 580-598. New York, 1896.

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Kruft. Neues Jahrbuch für Mineralogie, Geologie und Palæontologie,
Verbrietung des Phosphorits im Altpalæozoicum Europas. Von L.
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